OCCASIONAL PAPER NUMBER 1
NOVEMBER, 1988

WETLANDS HABITAT MANAGEMENT THROUGH NUTRIENT ENRICHMENT

Nova Scotia
Department of
Lands and Forests

WETLANDS HABITAT MANAGEMENT

THROUGH NUTRIENT ENRICHMENT

by

REG MELANSON
and
FRED PAYNE

NOVA SCOTIA DEPART. OF LANDS & FORESTS
WILDLIFE DIVISION
P. O. BOX 516
KENTVILLE, N. S.
B4N 3X3

NOVEMBER 1988

90-00530/

TABLE OF CONTENTS

ACKNOWLEDGEMENTS i

LIST OF TABLES iii

LIST OF FIGURES v

LIST OF APPENDICES vi

ABSTRACT vii

INTRODUCTION 1

Objective 3

STUDY AREA 4

METHODS 7

Water Sampling 7

Chlorophyll "a" Sampling 8

Sediment Sampling 9

Aquatic Invertebrate Sampling 10

Nest Boxes 12

Macrophyte Transects 13

Macrophyte Introductions 13

Waterfowl Surveys 14

Breeding Pair Surveys 14

Brood Surveys 14

Timed Observations 14

Liming 15

Fertilization 15

Statistical Analysis 17

Water Chemistry 17

TABLE OF CONTENTS (cont.)

Aquatic Invertebrates..... 18

RESULTS AND DISCUSSIONS..... 18

Water Chemistry..... 18

Chlorophyll "a" 24

Sediments 25

Aquatic Invertebrates 27

Nest Boxes 30

Waterfowl Use and Production 31

Breeding Pairs 31

Broods 33

Timed Observations 34

Macrophyte Introductions 35

Macrophyte Transect 36

GENERAL DISCUSSION 37

COSTS 41

CONCLUSION 42

RECOMMENDATIONS 43

LITERATURE CITED 44

ACKNOWLEDGEMENTS

There has been much input from a variety of groups and individuals into this project since its conception. Foremost, credit must go to George Boyd who spent many arduous hours in site preparation and data collection. A thank you goes to those at the Biology Department of Acadia University who have patiently answered many questions and allowed access to technical equipment. A special thank you to Dr. Mike Brylinsky who acted as advisor for the writing of this report.

Ducks Unlimited Canada deserves thanks for making funds available for the purchase of fertilizer, payment of wages for casual help, construction of the experimental impoundment and advice. We also want to thank Dr. Joe Kerekes of Environment Canada for his interest and assistance and Dr. John Underwood, Nova Scotia Department of the Environment and Peter Austin-Smith, Nova Scotia Department of Lands and Forests, for review of the manuscript.

A special thanks to Bowater Mersey for unrestricted access to their lands and occasional use of their facilities.

Appreciation is extended to David Wills for drafting of figures, Gerald Gloade and Mark Pulsifer for art work and the following for their assistance in data collection: Steve Anderson, Mark Elderkin, Lance Laviolette, Chuck Mader, Brian Pellerin, and the technical staff of the Wildlife Division. We also thank Lillian Farmer for typing the manuscript.

LIST OF TABLES

TABLE		PAGE
1	Physical Characteristics of Jordan Lake.....	50
2	Chemical Characteristics of Jordan Lake.....	50
3	Fauna of Jordan Lake.....	51
4	Flora of East Bay.....	52
5	Water Sample Dates.....	53
6	Statistical Data on Water Chemistry - April through August.....	54
6a	Statistical Data on Water Chemistry - April through August.....	19
7	Pre and Post Fertilization Water Chemistry.	60
8	Average Monthly Water Chemistry Levels: 1984-87.....	61
9	Average Yearly Water Chemistry Levels.....	65
10	Pre and Post Liming Water Chemistry.....	66
11	Lake Sediment Analysis by Year.....	67
12	Analysis of Lake Sediment - Pore Water for Fall of 1987.....	68
13	Invertebrate Statistics.....	69
14	Total Aquatic Invertebrate Numbers by Year and Order.....	70
15	Aquatic Invertebrate Trophic Levels by Rank and Year.....	71

LIST OF TABLES (Cont'd.)

16 Comparison of Aquatic Invertebrates (Trophic Relationship) Between the Control (C) and Experimental (E) Plots 1984-1986..... 72

17 Dry and Ashless Weights for Aquatic Invertebrate Samples..... 73

18 Nest Box Results..... 74

19 Jordan Lake Breeding Bird Surveys..... 75

20 Jordan Lake Brood Data 1984-87..... 76

21 Timed Observations..... 77

22 Vegetative Transect..... 78

LIST OF FIGURES

FIGURE		PAGE
1	Tobeatic Management Unit.....	80
2	Jordan Lake and Black Duck Lake.....	81
3	Diagram of Experimental and Control Areas.....	82
4	Diagram of Tower and Invertebrate Sampling Points.....	83
5	Diagram of Water and Sediment Sample Points.....	84
6	Diagram of Nest Box Locations.....	85
7	Diagram of Macrophyte Transect.....	86
8	Graph Showing Aquatic Invertebrate Trophic Changes.....	87

LIST OF APPENDICES

APPENDIX		PAGE
A	Black Duck Broods Recorded - Tobeatic Wildlife Management Area.....	89
B	Map of East Bay and Experimental Impoundment with Diagram of Control Structure.....	90
C	A General Classification System for Aquatic Insect Trophic Categories. (Cummins 1969).....	91
D	Observation Record Card.....	93
E	List of General Feeding Characteristics and Aquatic Invertebrates That Fall Under Them.....	94
F	Aquatic Invertebrate Summaries (Numbers) by Order, Month and Year.....	103

ABSTRACT

The vast majority of freshwater wetlands in Nova Scotia are oligotrophic and do not support a diverse or abundant floral and faunal community. During the summer of 1984 a nutrient enrichment project was undertaken in an attempt to increase the food source for wetlands related wildlife and consequently increase wildlife useage on a 4.9 ha impoundment in East Bay, Jordan Lake, Nova Scotia. Nitrogen and phosphorus levels in the impoundment were elevated through the addition of Urea and Triple-Super-Phosphate fertilizers in 1985 through 1987. The effects of fertilization were evaluated through the monitoring of water chemistry, macrophyte growth and diversity, aquatic macroinvertebrate biomass and diversity and wetlands related wildlife use. During the three years of fertilization, aquatic invertebrate numbers increased by 516.8%, plant diversity increased from 0.379 sp/m to 0.692 sp/m and wildlife sightings increased from 4 to 8 sp/observation. Spring use by breeding waterfowl of the fertilized impoundment increased from 2.9% to 87.2% of the total birds using East Bay. Brood use increased from 14.3% to 63% of the total broods utilizing East Bay. The project was cost effective since the total fertilizer cost over the life of the project was \$29.11/ha/y_1 or \$99.83/brood y_1, \$39.67/brood/y_2

and \$11.78/brood/y_3 . It is apparent that nutrient enrichment has the potential to be an important tool for wetlands enhancement. Further study is needed to refine techniques and determine downstream environmental effects, if application is to be adapted to open systems.

INTRODUCTION

Waterfowl brood data have been collected in Nova Scotia since the early 1960's. Analysis of these records indicate that some areas consistently produce high numbers of broods while other areas produce low numbers or no broods at all.

In the late 1970's a program was initiated by the Wildlife Division, Department of Lands and Forests, to determine what characteristics were common to high brood producing areas. Areas staging the greatest number of broods per hectare were found to be primary sewage lagoons. This situation was unexpected as ponds of this nature would be classified as "poor" waterfowl habitat using traditional evaluation criteria. The only common physical factor among the "better" brood producing areas was stabilized water levels. The "better" brood producing areas received effluent of some form (domestic or agricultural) or were situated on naturally fertile soils. Some of these areas were field checked and found to have abundant aquatic invertebrate populations (Payne, unpub. report). Sugden (1973) found that ducklings depend principally on aquatic invertebrates for food immediately after hatching. Beard (1953) also states that, "Ducklings of all species rely almost entirely upon animal foods during the first two

or three weeks of their existence." Holm and Scott (1954), Krapu (1974), Swanson and Meyer (1973) and Nilsson (1978) have all found that high protein diets are important to females for satisfactory breeding and egg production. The common denominator for areas productive of dabbling ducks appears to be an abundant food source in the form of invertebrates. The Land Capability Index for Wildlife-Waterfowl produced by the Canada Land Inventory (1970) states, "In general, the lakes of the Nova Scotia mainland portion are severely limited for waterfowl production by water depth and fertility." Simmons et al. (1984) feel that insufficient nutrients in the soil and/or water inhibit the growth of vegetation and adequate insect habitat necessary for waterfowl production. The resulting low rate of primary productivity is reflected in both low diversity and low abundance of bird, mammal, amphibian and reptile populations.

Public ownership and non-market pricing of most wild animals offers little economic incentive for the producer (land owner) to consider, much less invest in, the maintenance or increased production of wildlife resources. In Nova Scotia approximately seventy five percent of the land base is owned by private individuals or enterprise and it is generally the poorer quality, more sterile

habitats which have remained under public control. It is these infertile areas which, through management, offer a potential to produce more wildlife per unit of area and thus mitigate losses due to draining and filling in more developed regions.

Recent habitat evaluation studies at Black Duck Lake (Payne et al, 1983) on the Tobeatic Wildlife Management Area further substantiates the premise that nutrient levels determine freshwater wetland productivity and that small wetland units can be intensively managed to significantly increase wild animal diversity and abundance.

There are many thousands of small shallow water coves in the 6,674 lakes of Nova Scotia. Many of these coves are surrounded by Crown lands and can be managed in the public's interest. These coves, as well as portions of independent natural and managed wetlands offer a potential for wetland wildlife habitat management which has far reaching implications and which deserve testing.

OBJECTIVE

A. To determine the response of wetlands related wildlife, specifically waterfowl, to a controlled wetlands nutrient enrichment experiment through the introduction of inorganic

fertilizers. This was achieved by evaluating the following parameters:

1. Water chemistry (hardness, alkalinity, conductivity, pH, total phosphorus and total nitrogen).
2. Chlorophyll "a".
3. The density, taxonomic diversity and biomass of free swimming and benthic aquatic macroinvertebrates.
4. Wildlife use.
5. Changes in vegetative diversity.
6. The ability of the area to support high nutrient demanding aquatic plant species through introductions.

B. Evaluate the economic practicability of using fertilization as a principal management tool for enhancing waterfowl management areas.

SELECTION OF THE STUDY AREA

The Tobeatic Resource Management Area is located in the interior of Southwest Nova Scotia at the convergence of Digby, Yarmouth, Shelburne and Queens Counties and covers more than 103,600 hectares (Fig. 1). Included in the management area are 130 lakes which occupy 8,288 hectares.

Jordan Lake (Fig. 2), the site chosen for this study in the Tobeatic Resource Management Area, covers approximately 1,267 hectares. With its irregular shoreline, existing facility for water level control, oligotrophic condition, no hunting status and the representativeness of its fen and organic based aquatic systems, Jordan Lake is an exceptionally good area upon which to test and demonstrate wetland management procedures. Table 1 lists the physical characteristics of Jordan Lake and Table 2 presents an overall chemical description. A fauna list is set out in Table 3 and a flora list in Table 4.

Of 30 units (bays, inlets, etc.) with a water depth less than 1 meter, the opportunity exists to isolate 20 of these units from interaction with the main water body by booming or causeway construction. These units make up more than 251 ha. in total and average about 2.2 hectares. The largest of these units, East Bay, at 97 hectares has approximately 80 hectares that could be managed independently of the lake proper should this be considered advisable in the future.

Black duck brood survey data are available for certain years and areas within the Tobeatic Management Area since

1962 (Appendix A). Black duck production estimates were made in the early 1960's and a 100 square mile block helicopter brood survey including Jordan Lake and flowage was flown in 1977. Beaver studies including "lodge" surveys of Jordan Lake were carried out periodically during the 60's and 70's and a fisheries survey was conducted in 1974.

A preliminary fertilization study at Black Duck Lake in the Tobeatic was initiated in 1980, the results of which add promise to this redirected management study (Fig. 2). A 4.9 hectare impoundment was constructed by Ducks Unlimited Canada in the fall of 1985 in East Bay (Appendix B). This impoundment served as the experimental area for nutrient enrichment and was created by constructing two earthen dykes totalling two hundred and fifty-six metres in length. The impounded area has a total of 1,127 metres of shoreline with water level controlled by a flap gate (Appendix B).

The control area is a section of Jordan Lake lying due North and adjacent to the Ducks Unlimited impoundment but not physically isolated from the lake proper. The experimental area and control were arbitrarily divided into two sections (A-1 and A-2 = experimental; B-1 and

B-2 = control) (Fig. 3). Observation towers for the purpose of conducting timed wildlife sightings were built by constructing platforms in trees on the experimental and control areas (Fig. 4). Tower "A" (approximately 30' high) enables one to see most of compartment "A" while tower "B" (approximately 20' high) lets one observe the north end of compartment "A" plus all of compartment "B".

METHODS

Water Samples

Water samples were collected from the experimental and control areas from April through November (Table 5) in the years 1984 through 1987 (Fig. 5). Two samples consisting of a minimum of 250ml each were collected from the experimental area and one sample from the control by submerging a plastic Nalgene bottle approximately 50 cm below the surface before obtaining the sample. The refrigerated samples were delivered as soon as possible to the Pathology Lab, Victoria General Hospital, Halifax for analysis. Chemical parameters measured and analysis techniques used were calcium and magnesium (inductively coupled plasma method); hardness (calculated using calcium and magnesium results); alkalinity (automated colormetric

procedure using Brom Phene (Blue)); conductivity (radiometer conductivity meter); pH (radiometer pH meter); total phosphorus (automated UV irradiation procedure using ascorbic acid); and total nitrogen (automated UV digestion).

Chlorophyll "a"

Water samples for chlorophyll "a" analysis were taken in conjunction with the other water samples. These samples were transferred to a 1000ml graduated cylinder and then filtered through a 55mm 934AH glass fibre filter using a Buchner type pyrex vacuum funnel with perforated plate, a 2000ml pyrex vacuum flask and a Nalgene hand operated PVC vacuum pump. One milliliter of 20% magnesium carbonate solution was added to the funnel initially with the water. Filtration was carried out until the entire sample was filtered or the filter paper became clogged. The filter paper was then removed by using forceps and the filter paper was folded and inserted into a 21 x 70 mm 4 dram bottle without being capped to facilitate drying of the sample. Each bottle was labeled as to location, date, amount of water filtered and kept cool or frozen until it could be delivered to the Pathology Lab in Halifax where it was analyzed using a fluorimetric technique

after extraction in acetone.

Sediment Samples

Sediment samples were taken in the experimental and control areas in 1984 through 1986 using a core sampler (Fig. 5) and analyzed at the Nova Scotia Agricultural College in Truro. Parameters measured and testing methods used were conductivity (1:2 soil/liquid solution by volume in distilled $H_2 0$ with results taken by a standard conductivity meter); pH (1:1 solution by volume in distilled $H_2 0$ with results taken by volume using a Bray solution -.05N ammonium chloride, .1N hydrochloric acid with extract read on an auto-analyzer); $K_2 0_5$, Ca and Mg (1:10 solution by volume of 1N ammonium acetate at pH of 7 with results obtained by atomic absorption) and total P (sample digested with sulfuric acid and 30% hydrogen peroxide in a block digester at 350° and results obtained on an auto-analyzer).

It was felt a stratified sampling of the sediments would be more beneficial as it would show the amount of phosphorus that is available at the sediment/water interface as well as deeper through the sediments. Lee (1986) found that conventional methods of soil analysis are inappropriate for lake sediments.

In November, 1987, four interstitial water sampling devices (two in the experimental and two in control) were installed and then removed in December 1987. These devices consisted of a piece of clear plexiglass approximately 80cm x 25cm x 1cm with two rows of 1cm x 10cm compartments spaced at 1cm intervals the entire length. These compartments were filled with distilled water and then covered with a sheet of dialysis membrane which was secured in place. The sampler was then placed in a bath of degassed distilled water to allow most of the dissolved gases to leave by equilibration (Hesslein, 1976). The samplers were then pushed into the sediments as deep as possible without covering the top of the sampler in the sediments. When the samplers were removed, water from each compartment was emptied by rupturing the membrane and a syringe was used to remove the sample which was then transferred to a clean vial. Each water sample taken was tested for conductivity, pH and soluble reactive phosphorus (molybdate blue technique) at Dalhousie University by the Canadian Wildlife Service staff in Halifax.

Aquatic Invertebrates

Aquatic invertebrates were sampled at a number of sites (Figure 4) in the experimental and control areas four

times a year in mid-May, June, July and August of 1984 - 86. Samples were not collected in July or August from the control sites in 1987 due to low water conditions but samples were taken from the experimental area for 1987. The aquatic invertebrate sampler consisted of a round plastic can (67 cm high X 55.5 cm wide at the top X 48 cm wide at the bottom) with the bottom removed. Samples were obtained by dropping the sampler into the water at the sample site while twisting it into the bottom sediments so as not to allow the invertebrates to enter or leave via the bottom.

Once the sampler was in place a hand net (24.5 cm X 16.5 cm with a 1.5 mm mesh) was used to make five complete circular sweeps top to bottom inside the sampler. After each sweep the contents of the net were emptied into a seive bucket (1 mm mesh) and washed. The remaining sample matter after washing was then transferred to a plastic bag, labeled (date, location) and kept in a cool place until it could be frozen or the invertebrates removed. Five sample plots comprise one sample and two samples were taken in each compartment. The frozen samples were later thawed, rewashed through a hand seive and all invertebrates were identified to order, (Pennak 1978,

Merrit and Cummins 1984), counted and placed in 70% ethanol. Samples for 1984 and 1986 were identified and assigned a feeding trophic level (Cummins 1973) (Appendix C). Samples for 1984, 1986 and 1987 were dried for forty-eight hours in a vacuum dryer at 105°C. The samples were then weighed using a Mettler electronic scale and the ash content determined by burning for twenty-four hours at 500°C. The ash weight was determined in the same manner as the dry weight.

Nest Boxes

Nest boxes were constructed for tree swallows (Indoprocone bicolor) and cavity nesting ducks, (wood ducks (Aix sponsa) and hooded mergansers (Lophodytes cucullatus)) and erected on 11 April 1984 in the experimental and control areas (Fig. 6). Four duck boxes and three swallow boxes were erected in the experimental area and three swallow boxes and three duck boxes were erected in the control. One duck box and one swallow box were erected just outside the south-west corner of the control. In the winter of 1985 ten additional duck nesting boxes were erected throughout East Bay.

Macrophyte Transects

A vegetative belt transect one meter in width was run from the north end of the control to the south end of the experimental area on 17 July, 1984 (Fig. 7). All vegetation falling within the transect was recorded. A portion of this transect was again run in the experimental area on 22 July, 1987. Due to low water conditions in the control, this section was not resurveyed.

Macrophyte Introductions

Little Duckweed (*Lemna minor*) and Cattail (*Typha latifolia*) were introduced to the experimental and control areas in June, 1984, 1985 and 1986. Big Burreed (*Sparganium eurycarpum*), Wild Rice (*Zizania aquatica*), Common Elodea (*Elodea canadensis*) and Water Milfoil (*Myriophyllum sp.*) were introduced to the experimental and control areas in June 1986. Star Duckweed (*Lemna trisulca*) was introduced to both the experimental and control areas in June 1986.

Waterfowl Surveys

Breeding Pair Surveys

Waterfowl breeding pair surveys were conducted by canoe during the last week of April in 1984, 1985, 1987 and 1988, and the first week of May in 1986. All waterfowl were noted as to whether they were single birds, pairs or flocks.

Brood Surveys

Helicopter brood surveys were conducted in 1984 with canoe and quiet observation surveys carried out in 1985, 1986 and 1987. In helicopter surveys two observers were used and the helicopter swept back and forth over the area being surveyed. In canoe surveys two people were required with only one person doing the observing. The observer had to stand in the canoe a great deal of the time in order to see through the vegetation.

Timed Observations

Timed observations to compare use by waterfowl and other wildlife species between the experimental area and the

control were carried out from towers (Figure 4) in May, June, July and August in 1984, 1985, 1986 and 1987. All observations were recorded on a record card (Appendix D).

Liming

Ten tonnes of dolometic limestone were spread at the approximate rate of 2T/ha by snowmobile on the experimental area over the snow on Jan. 15, 1985. This was carried out to raise the pH of the experimental area to an approximate value of 7.

Fertilization

In 1985 the fertilizer was bought in a Triple-Super-Phosphate/Urea pre-mix at a rate of ten parts nitrogen to one part phosphorus (109.5kg Urea to 25kg Triple-Super-Phosphate). The intent was to raise the total phosphorus level of the experimental area to 2000 mg/m^3. Fertilizer load was calculated through the following formula:

Triple-Super-Phosphate (Kg) = desired phosphorus load ($mgPm^3$) x volume of area to be fertilized log^{-6} x 4.986.

Urea (Kg) = amount of phosphorus to be loaded (Kg) x 10 x .46.

On 15 May, 1985, 750 kg of the fertilizer was dissolved in approximately 3,200 litres of lake water. This mixture was transferred by a gravity fed hose to two 205 litre drums that were connected at the bottom by a 10 cm pipe that allowed the mixture to flow freely from barrel to barrel. An electric sump pump with the capacity to pump 228 lpm was floated in one of the drums of fertilizer slury and connected to the centre of a 3.7 m boom. This boom is constructed of 5 cm ABS plastic pipe with each end capped and 6 mm holes spaced at approximately 12 cm centers drilled down one side. The complete apparatus was mounted on a flat bottom boat powered by a 6 hp motor with a portable gas generator supplying power to run the sump pump. When the 205 l drums were filled, the boat was driven over the experimental area with the fertilizer mixture being sprayed onto the water until the full 3,200 litres were spread. Care was taken to uniformly cover the entire area.

On 5 June, 1985, 275 kg of the fertilizer mix was transferred to eleven jute bags and hung off stakes throughout the marsh to try and facilitate a slow release that would maintain desired nitrogen and phosphorus levels. On 22 July, 1985, 155 kg of the fertilizer was again put into burlap bags and hung throughout the experimental area as was done on 5 June, 1985.

On 6 May, 1986, 225 kg of Triple-Super-Phosphate was dissolved in approximately 2,275 litres of water and pumped over the experimental area as in 1985. On 19 June, 1986, 125 kg of Urea was broadcast by hand over the area. On 22 July, 1986, 150 kg of Urea and 75 kg of Triple-Super-Phosphate were mixed and put in eleven burlap bags and hung throughout the area as in 1985.

On 13 May, 1987, 100 kg of Urea and 100 kg of Triple-Super-Phosphate were dissolved in approximately 1,640 litres of water and sprayed over the area as in 1985 and 1986. Jute bags were not filled with fertilizer and hung throughout the area as in 1985 and 1986.

Fertilizer application was timed so as to reduce loss due to spring flushing and to be available during peak macrophyte growth.

Statistical Analysis

Water Chemistry

An "F" test was performed on the water chemistry data to determine the homogeneity of the variances with highly significant "F" values considered indicative of unequal

variances. Appropriate students-t tests were then applied to determine if there was a significant ($P<.05$) difference in the sample parameters (hardness, alkalinity, conductivity, pH, total phosphorus and total nitrogen) between the experimental and control areas for 1984 through 1987. The differences within the experimental and control areas for 1984 through 1987 were also examined (Table 6 and 6a).

Aquatic Invertebrates

A Wilcoxon's signed-rank test was performed on the data for 1984 and 1986 (Table 13) to determine if the observed differences in aquatic invertebrate numbers between years and sample areas are significant ($P<.05$).

RESULTS AND DISCUSSIONS

Water Chemistry

There is no significant ($P>.05$) difference between the experimental and control areas for hardness, alkalinity, conductivity, total phosphorus or total nitrogen for 1984. There is, however, a significant ($P<.05$) difference in pH with the yearly means being 5.30 for the experimental and 5.16 for the control in 1984.

Table 6a. Statistical comparison of chemical characteristics between the experimental and control areas and within the experimental and control areas for 1984 through 1987 (April through August).

Experimental vs Control

Year	1984	1985	1986	1987
Hardness	N	**	**	**
Alkalinity	N	**	*	**
Conductivity	N	**	*	N
pH	*	**	**	*
Total Phosphorus	N	N	N	*
Total Nitrogen	N	N	N	*

Experimental vs Experimental (Control vs Control)

Year	84-85	84-86	84-87	85-86	85-87	86-87
Hardness	**(*)	*(N)	*(N)	**(N)	**(N)	N(N)
Alkalinity	**(N)	**(N)	**(N)	**(N)	**(N)	N(N)
Conductivity	**(N)	**(N)	N(N)	**(N)	**(N)	*(N)
pH	**(**)	**(**)	**(*)	**(N)	*(N)	N(N)
Total Phosphorus	N(N)	N(N)	*(N)	N(N)	N(N)	N(N)
Total Nitrogen	N(N)	N(N)	*(N)	N(N)	N(N)	N(N)

N = Not significant
* = Significant at 95%
** = Significant at 99%

There are no significant (P>.05) differences in phosphorus and nitrogen readings between the experimental and control plots until 1987 when the change in both phosphorus and nitrogen levels became significant (P<.05). Similar trends are exhibited for nitrogen and phosphorus within the experimental area with the only significant (P<.05) period being 1984-87 for both parameters. There are no significant (P>.05) differences noted for any of the two year test periods in the control for phosphorus or nitrogen.

The highest peaks in phosphorus were recorded the day following fertilization (Table 7) and levels then declined until an equilibrium was reached. Smith (1969) found concentrations of phosphorus to be highest two days after fertilizing with granular superphosphate and one day after fertilizing with Triple-Super-Phosphate. Work by Shearer et al. (1987)on a small deep lake showed an equilibrium was quickly reached with most of the phosphorus being sedimented out. Levine et al, (1986) discovered very little of the phosphorus (<4%) that reached the sediments was injected back into the water column at the water sediment interface in their radiotracer study of phosphorus cycling.

The mean hardness value (Table 9) increased from 4.4 mg/l $CaCo_3$ to 21.4 mg/l $CACo_3$ within the experimental area between 1984-85 which represents a highly significant ($P<.001$) difference (Table 6, 6a). Hardness values decreased in 1986 and 1987 but are highly significant ($P<.001$) for both the 1985-86 and 1985-87 periods. No significance ($P>.05$) is shown for the 1986-87 test. Hardness values decreased in 1986 and 1987 when compared to the 1985 levels but they are still high enough to be significant ($P<.05$) for the 1984-86 and 1984-87 periods. A significance ($P<.05$) shows up in the 1984-85 comparision but all other tests are not significant ($P>.05$) in the control area. By comparing the experimental area to

the control area, a highly significant difference is shown for 1985 ($P<.001$), 1986 ($P<.01$) and 1987 ($P<.01$) for hardness.

The increase in alkalinity (Table 9) in 1985 resulted in a highly significant ($P<.001$) change over 1984 in the experimental area. As with hardness, alkalinity levels declined in 1986 and 1987 with the decreases being highly significant ($P<.001$) for 1985-86 and 1985-87. The changes in 1986-87 were not significant ($P>.05$). Though alkalinity levels decreased in 1986 and 1987, they were still high enough in 1987 to be highly significant ($P<.01$) when compared with the pre-treatment levels of 1984. No significant ($P>.05$) changes occurred in the control area over the same time period. In comparisions between the experimental and the control areas, a highly significant ($P<.001$) difference occurred in 1985 and 1987 with a significant ($P<.05$) difference in 1986.

Data from the experimental area (Table 6, 6a) for conductivity shows a highly significant increase for 1984-85 ($P<.01$) and 1984-86 ($P<.001$). Conductivity inceased in 1985 and then decreased in 1986 and 1987 as did hardness and alkalinity. Hardness and alkalinity

levels are still high enough in 1987 to be considered significant ($P<.05$) but conductivity levels have dropped lower in 1987 than pre-treatment levels with no significant ($P>.05$) difference noted for 1984-87. No significant ($P>.05$) changes occurred in the control area over the same test periods. Comparisions of the experimental area with the control show a highly significant ($P<.01$) increase in 1985, a significant ($P<.05$) increase in 1986 and no significant change ($P>.05$) for 1987.

All pH data were converted to natural logarithms (Table 6) for analysis. The experimental and control areas both experienced highly significant ($P<.01$) increases for the 1984-85 and 1984-86 periods (Table 6, 6a). In 1984-87 comparisons, the differences in the experimental and control areas were both significant ($P<.05$). In the experimental area the decrease in 1985-86 and 1985-87 were both highly significant ($P<.01$). The data for 1986-87 show no significance ($P>.05$) difference. There are no significant ($P>.05$) differences in the control for 1985-86, 1985-87 and 1986-87. When comparisions are made between the experimental and control areas, a significant ($P<.05$) change for 1984 and 1987 and a highly significant ($P<.01$) change in 1985-86 occurs.

The monthly means for all sample parameters (hardness,

alkalinity, conductivity, pH, total phosphorus, and total nitrogen) by year is presented in Table 8 with the yearly averages in Table 9. Table 10 presents pre and post liming and pre fertilization data. This initial data points to the probability that fertilization did not have a dramatic effect on hardness, alkalinity, conductivity or pH levels. Other fertilization projects show similar results. Ross et al (1979) saw no significant change in pH after fertilizing with nitrogen and phosphorus. Total hardness and alkalinity did not differ greatly in ponds enriched by Boyd (1981) with fertilizers containing varying amounts of nitrogen and phosphorus while Smith (1969) found little change in specific conductance after fertilization.

Liming of acidic waters invariably results in an increase in alkalinity and pH and contributes to an increase in water hardness (Fraser et al. 1982) which all combine to increase specific conductance (Wetzel 1983).

The means for alkalinity and specific conductance have been declining yearly since liming (Table 9). Strong (1987) also found this to happen in his lake liming project. This phenomenom can be attributed to the added base being flushed out of the basin and or being tied up in the sediments.

Chlorophyll "a"

Chlorophyll "a" levels for 1984 through 1986 were analyzed to determine if a significant positive correlation exists between chlorophyll concentration and total phosphorus. In the experimental area, a negative correlation ($R=-.2504$) is found but it is not significant ($P>.05$). In the control area, a positive correlation ($R=.8096$) which is highly significant ($P<.001$) is shown. It is possible that in the experimental area plytoplankton production is limited by other factors, such as light penetration, if phosphorus and nitrogen are in excess (Brylinsky, pers. comm.) The increased productivity of emergent and submergent (particularly E. canadensis) macrophytes and the subsequent shading caused by these plants coupled with the natural dark coloration of the water will greatly restrict euphotic zone depth. Hasler et al (1949) and Coulder (1969) both conducted studies in which they concluded plytoplankton growth can be restricted due to shading by dense stands of macrophytes. Work carried out by Planas et al.(1981) showed that production of phenolic compounds by Myriophyllum spicatum inhibits phytoplankton growth. Myriophyllum sp. production has increased in the experimental area and it is possible that other plants may be producing phenolic compounds that retard or inhibit

phytoplankton production.

Sediments

Core Sampling

The sediment sample results are inconclusive with regard to liming, since higher pH, calcium and magnesium levels are found in pre-liming samples as compared to post liming samples (Table 11). There is an increase in phosphorus levels one year after fertilization with $P_2 O_5$ levels increasing from 30 kg/ha to 50 kg/ha in the experimental plot while the control remains relatively constant (30 and 29 kg/ha). In total P(ppm) there has been a slight increase going from 433 to 468 ppm in the experimental with the control again remaining relatively constant (440 - 450 ppm).

Interstitial Samples

A comparison of the experimental and control plots (Table 12) shows that in the control pH values are low at the sediment surface and increase with depth. In the experimental plot, pH reaches a peak at 11 to 15 cm then decreases until 51 to 55 cm where it begins to increase again. It remains below the pH value of the control

for that depth. As depth increases, pH in the control and experimental plots should merge to a constant. The experimental plot pH reaches a peak at 11 to 15 cm with a value of 7.40 while the control has a value of 6.72 at the same depth. In conductance, the same trend as pH is exhibited with a peak of 145.60 reached at the 21 to 25 cm depth in the experimental plot while the control levels are still increasing by the end of the sample (51-55 cm).

The differences in pH and conductance levels between the experimental and control plots at the sediment water interface were not great (6.65 vs 5.88 and 52.0 vs 42.0 respectively) but a dramatic difference existed in the levels of soluble reactive phosphorus (SRP) with a reading of 0.110mgl1 for the experimental and a reading of 0.004 mg/1 for the control. SRP peaks at 0.598 mg/1 at 26 to 30 cm in the experimental plot while the control peaks at 0.039 mg/1 at the 46 to 50 cm level.

Cross et al. (1983) found a similar trend for phosphorus, that is, low values at the surface, then increasing to a peak with depth and finally a decrease in their studies. They contributed this to the changing composition of sedimenting materials and not the downward migration of P. The exchange of phosphorus between sediments and

the overlying water is a major component of the phosphorus cycle in natural waters with an apparent net movement of phosphorus into the sediments in most lakes (Wetzel 1983).

The peak in SRP at 36 to 40 cm is too deep to have resulted from a layer of decomposing organic material that had accumulated due to increased production in the system. This peak is in all probability a result of the leaching of phosphorus that had been added and then sedimented. The increased invertebrate activity along with sediment consistency is also possibly a factor in the amount of phosphorus that was present at this depth.

Aquatic Invertebrates

The data shows that no significant ($P>.05$) difference exists between the experimental and control areas for 1984 but a highly significant ($P<.01$) difference does occur for 1986. When comparing the samples taken from the experimental area in 1984 against samples taken from the same area in 1986, a highly significant ($P<.05$) difference is calculated while the control area shows a significant ($P<.05$) change for the same time period.

Total invertebrate numbers in the experimental plot

increased by 113% between 1984-85, 511% between 1984-1986 and 517% between 1984-87 (Table 14). The biggest increase over the four year sampling period was shown by isopods (7,324%) followed by gastropods (1,106%), coleopterans (668%) and dipterans (371%) of which 99% are Chironomidae. The dipterans peaked in 1986 when they ranked first and increased by 673%. Numbers of all invertebrate groups increased over the four year period with the exception of amphipods which were absent in the 1987 samples.

Total invertebrate numbers in the control area increased by 34% between 1984-85 and 150% between 1984-86 (Table 14). Only two samples were obtained from the control in 1987 due to low water conditions so the 1987 data is not available for comparison. The greatest increase in numbers from 1984-86 was in dipterans (365%) followed by amphipods (191%) and trichopterians (74%). All other orders, excepting Ephemeroptera and Hirundinae (neither represented in 1984 samples) decreased in numbers over this time period. The main component responsible for the yearly increases in the control are the dipterans as they constituted 45% of the total numbers in 1984, 67% in 1985 and 83% in 1986. When dipterans are removed from the data, a decline in total numbers of 20% from 1984-85 and 22% from 1984-86 is realized (Table 14).

Samples from both the control and experimental areas

for 1984 and 1986 were identified beyond order to be able to determine trophic level. (Cummins 1973, Merrit and Cummins 1984) (Appendix E). This was done to determine what changes may have occurred in the trophic structure of the sites. The data (Table 15) shows collectors form the largest species group followed by predators in both the experimental and control areas in 1984 and 1986. In 1984 the third and fourth largest populations were shredders and scrapers respectively for the experimental area with the reverse being true for the control area.

In 1986 the third and fourth ranks changed positions in both the experimental and control areas (Fig. 8). When individual feeding characteristics are compared, the greatest increase (1984-86) in the experimental area is in the filter/suspension feeders and organic scrapers. These two components combined made up 67% of total sample numbers in 1984 but increased to 91% by 1986. This compares with 57% and 69% for the control area.

As stated earlier, numbers of all species, excepting amphipods, increased over the four year period in the experimental area. When comparing trophic level composition, a negative shift occurred in 63% of the species due to an increase in the number of

filter/suspension feeders (Table 16). A similar situation occurred in the control data.

Table 17 compares total yearly dry weight for 1984, 1986 and 1987 for the experimental area and 1984 and 1986 for the control. There was a 102% increase in dry weight between 1984-86 and a 117% increase between 1984-87 for the experimental area. The control experienced a 27% decrease in weight from 1984 to 1986. After ashing it was found the ashfree content decreased from 81% in 1984 to 53% in 1987 in the experimental area. This can likely be attributed to the increases in gastropods (1,106%) and pelecypods (75%) over the sampling time.There was a decrease in the ashfree weight from 87% in 1984 to 79% in 1986 in the control which probably reflects natural variability.

An attempt was made to correlate nutrient levels with aquatic invertebrate populations. The state of the existing data does not lend itself to this type of analysis due to the highly variable swings in total phosphorus and total nitrogen levels.

Nest Boxes

In 1984, six of the swallow boxes were used while only

four were used in 1985. By 1986 all seven boxes were used and this was again repeated for 1987 (Table 18). Use is probably not food related but rather related to nest box availability.

None of the wood duck boxes were used in 1984 but two broods, one each in the control and experimental area, were produced in 1985. During the winter of 1985 ten additional boxes were erected in East Bay and in the summer of 1986 two of these boxes along with another one in the control and two in the experimental area were occupied. In 1987 one box in the experimental area, none of the control boxes and three in East Bay were used (Table 18). None of the boxes have been used twice and no pattern indicating preference for location has emerged. All boxes are close enough to the fertilized area so that any broods produced in them can easily be taken there to feed.

Waterfowl Use and Production

Breeding Pairs

Nutritional requirements of breeding waterfowl vary by species and within species by sex (Krapu 1981, Hohman 1985) with the females requiring a diet high in protein

and calcium for egg production (Krapu 1974, Reinecke et al. 1980). Much work has been carried out on the importance of aquatic invertebrates to breeding waterfowl (Hohman 1985, Landers et al. 1977, Reinecke et al. 1980, Reinecke 1979) as a very high source of protein (Reinecke 1977). It is felt that invertebrate availability may be a determining factor in clutch size (Krapu and Swanson 1975) and birds may time egg laying to coincide with peak invertebrate abundance (Krapu 1974, Hohman 1985).

The yearly breeding pair numbers (Table 19) show a positive relationship with yearly aquatic invertebrate numbers in Table 14. As invertebrate numbers in the fertilized area increased, so has waterfowl use. It appears that most of the birds in the fertilized area are being drawn from East Bay (Table 19).

The high calcium requirements of females for egg laying may be met through predation on molluscs, isopods and ephemeroptera (Reinecke et al. 1980). Table 14 shows that molluscs (gastropods and pelecypods), isopods and ephemeroptera have all increased considerably and the high calcium availability associated with these groups may be a major contributing factor leading to increased waterfowl use.

Broods

After incubation, the female still needs access to a high invertebrate diet for a short while as her time for foraging is restricted by clutch attentiveness (Hohman 1985). Ducklings of all species rely almost entirely on invertebrates during the first two to three weeks of their existence. A transition occurs from a consistently high invertebrate diet in class I and II birds to a diet of mixed composition (plant/invertebrate) during class III (Whitman 1974, Hohman 1985). There is also a difference in preferred invertebrate foods between class I and class II birds (Reinecke 1979) but availability appears to be the most important factor determining foods consumed (Whitman 1974).

Comparison of data from Table 20 and Table 14 shows there to be a similar relationship with invertebrates and broods as there is with breeding birds. Joyner (1980) found a significant correlation between invertebrate numbers and duck use which suggested useage was regulated by invertebrate numbers. It is apparent here that useage and species diversity of waterfowl has increased with increases in invertebrate numbers. No actual physiological work was carried out on the ducklings at this time to determine if any significant differences exist between

the fertilized and non-fertilized birds. Broods moved freely in and out of the impoundment so no assessment could be made of brood survival in the fertilized vs non-fertilized area. As with breeding pairs, the fertilized plot appears to be drawing broods from East Bay (Table 20).

Timed Observations

Fourteen timed observations in the fertilized area and 12 in the control were carried out in 1984 with only four in the fertilized and control in 1987. The average length of observation in 1984 was 40.5 minutes for the fertilized plot and 38.8 minutes for the control with the average for both plots being 30 minutes in 1987. The most common species observed in the fertilized area in 1984 were tree swallows, red-winged blackbirds and ring-necked ducks but in 1987 the most common were red-winged blackbirds and swamp sparrow with wood ducks, hooded mergansers, common grackle and then swallows, all having the same number of occurrences (Table 21).

The most commonly observed species in the control were red-winged blackbirds, tree swallows and black ducks in 1984. Red-winged blackbirds and tree swallows were the most commonly observed but wood ducks, common snipe

and robins have similar occurrences in 1987 (Table 21).

The average number of species observed per timed period was 4 in 1984 and 8 in 1987 for the fertilized area (Table 21). The average number for the control was 5.1 in 1984 and 3.8 in 1987. This is a 100% increase in species diversity for the fertilized area and a 34% decrease for the control. The increase in bird species diversity can in all likelihood by attributed to the increase in invertebrate numbers and plant species diversity.

Macrophyte Introductions

All introduced plants in the experimental plot survived except Lemna trisulca. Elodea canadensis was the most successful introduction in the fertilized area with approximately 80% of the water covered areas now producing Elodea. The best productivity of Lemna minor was in sheltered areas. The only plant species to survive in the control area was one typha plant. Neely and Davis (1985) found that potential production of some emergent plants may be limited by nutrient availability. Lee (1970) feels that nitrogen and phosphorus are probably the key elements in controlling aquatic plant growth and the fertilization of natural waters may result in excessive growths of higher plants. Smith (1969) found

the quantities of rooted aquatic plants as a whole increased moderately over the years of his fertilization project. Studies by Boyd and Hess (1970) show a positive relationship between the biomass of Typha latifolia and phosphorus concentrations in the sediments and surface water. It appears that the main reason for the success of the introductions in the experimental plot is due to nutrient enrichment and that the failure of introductions in the control is due to nutrient limitations.

Macrophyte Transects

A 226.8 m section of plant transect A was surveyed in 1987 and compared to data collected for the same section in 1984 (Table 22). The average number of species per vegetative type for 1984 was 3.2 species and in 1987 it was 5.8 species. There were 0.379 sp/m in 1984 and 0.692 sp/m in 1987 which represents an 83% increase in species diversity.

Dulichium arundinaceum, the most commonly occurring species in 1984, was replaced by Elodea canadensis (an introduced species) in 1987. The second most commonly occurring species in 1987 was D. arundinaceum. E. canadensis occurred in 22 of the vegetative types in 1987 with D.

arundinaceum occurring in 17 types in 1984 and 16 types in 1987. There were no instances where a particular species died out.

GENERAL DISCUSSION

Productivity of an aquatic system is regulated by nutrient availability, temperature, solar radiation and morphology. The natural eutrophication of a water body can take thousands of years where as cultural eutrophication can occur in a few years (Lee 1970). Cultural eutrophication need not be a permanent situation and can be reversed. Schindler et al. (1987) found that the rate of recovery appears related to the length of time the lake has been eutrophic, completeness of phosphorus reduction, phosphorus residence time and probably sediment characteristics.

Fertilization of a water body increases all forms of organic life (Smith 1969, Lee 1970, Whitman 1974, Nilsson 1978, Ross et al. 1979, Payne et al. 1983, Kerekes et al. 1984, Findlay et al. 1987, Perrin et al. 1987). Much research has been carried out in the last decade to determine which of the primary elements, nitrogen, phosphorus or carbon are limiting to eutrophication (Findlay et al. 1987). The absolute amount of nutrients

available for productivity is an important factor but the ratio of the various elements to each other is also very important (Lee 1970). A nitrogen/phosphorus ratio of 10/1 is suitable for unlimited phytoplankton growth and an attempt was made throughout the growing season to maintain this ratio. Mills et al. (1987) found that a ratio of 5:1 resulted in blooms of nitrogen fixing algae which can later result in anoxic conditions, vertebrate die-offs, etc. Smith (1969) found lakes to be very efficient in self regulating biochemical processes by which added phosphorus is removed from biological cycling. Shearer et al. (1987) noted that within one year the major differences between an experimental and control area caused by phosphorus addition had virtually disappeared and after three years production had dropped in the experimental area to levels typical of the reference lake. These findings correlated with results observed in the experimental area in 1986 when the area became nitrogen limiting. Macrophyte and algae production was not at the level we hoped to achieve, so nitrogen was added in an attempt to raise the nitrogen/phosphorus ratio to 10:1. Within a week chlorophyll "a" levels increased and a marked change in macrophyte and algae production was noticeable.

Quantitative samples, other than the vegetation transect,

for macrophytes were not taken. Visibly, the effect of fertilization is very noticeable with the macrophytes in the experimental area exhibiting a denser and more robust and lusher condition than the control. Work by Kerekes et al. (1984) showed the macrophyte community of an acidified lake receiving nutrients from anthropogenic sources was much richer and denser than that of a similar lake not receiving nutrients. Work by Neely and Davis (1985) suggest that concentrations of nitrogen and phosphorus can influence production of emergent plants through the sequential process of moving from the surface water to sediments to plants. There is also a marked difference in the "greening up" of the experimental area compared to the control and the remainder of the lake. Davis and van derValk (1983) suspect that nutrients stored in below-ground structures at the end of the growing season probably influence the initiation of shoots in the next season.

Waterfowl use of the experimental area appears to coincide with growth stages that rely heavily on aquatic invertebrates and the number of waterfowl utilizing the area increased yearly. Whitman (1974) found that critical periods in the life cycle of breeding waterfowl apparently coincided with periods of high invertebrate populations. Our data shows a peak in invertebrate numbers in June

which coincides with the early stages of brood activity (Appendix F). Invertebrate data for April are not available but personal observations in April showed that the experimental area was extensively covered by exuviae from chironomidae larvae at a time when the area was frequently used by breeding waterfowl. This phenomenon was not observed in the control area.

Detrital biomass samples were not taken but personal observations point towards a high correlation between detrital buildup and invertebrate numbers. The greater the amount of detritus the more invertebrates. This appears to be especially apparent in early spring. Barkhouse (pers. comm.) also found this to be true in his invertebrate sampling. He feels his data may point to a positive relationship between type of detritus and invertebrate densities but the data has yet to be evaluated. Kaminski and Prince (1981) feel that decomposing detritus provides both escape cover and a food supply for invertebrates. Whitman (1974) found a relationship between dense emergent vegetation and invertebrate abundance. Most emergent plants are slower to break down and will create a layered detrital buildup of different stages of decomposition. Kaminski and Prince (1981) found high invertebrate populations were produced by mowing an area before flooding. By mowing, a ready

source of detrital material would be created. Two species of invertebrates important to black ducks as a food source, isopods (Reinecke and Owen 1980) and chironomids (Reinecke 1979) have both increased substantially in the fertilized area. Kerekes et. al. (1984) found aquatic invertebrate populations to be considerably richer in a fertilized acidic lake compared to a similar non-fertilized acidic lake. Joyner (1980) found a significant positive correlation between invertebrate numbers and waterfowl use suggesting waterfowl use may be regulated by invertebrate numbers.

COSTS

Initial results from the data collected to date suggests this particular technique of nutrient enrichment is economically acceptable on an operational level. Excluding labour and water analysis, fertilizer costs for 1985 were $199.66; $158.66 for 1986 and $61.47 for 1987, for a total of $419.79 for the three year period. This resulted in a total fertilizer cost over the three years of $29.11/ha/y . The cost per brood reduced drastically each year with the first year costing $99.83/brood; the second year $39.75/brood and the final year $11.78/brood. The decrease is due to fertilizer costs dropping yearly and brood numbers increasing.

The costs of application would depend on location of the area to be worked. Actual time required to fertilize the study area by spraying was approximately three hours for two people.

Water analysis would be required a year prior to fertilization and should be conducted at the least in spring, mid-summer and early fall. After this, one sample in May prior to fertilization to enable the manager to determine load is all that would be needed. The costs for analysis would depend on parameters looked at and where analyzed. Samples presently cost $38.50 each for analysis.

The costs of application depend on method adopted. A set-up similar to that used in this study area could be assembled for approximately $200.00.

CONCLUSION

The results of this study strongly suggest that because of nutrient enrichment, both productivity of aquatic invertebrates and plant diversity has increased. These changes have resulted in a positive response by waterfowl and other wildlife.

RECOMMENDATIONS

This study has shed some light on the economic and environmental practicability of using nutrient enrichment as a wetlands management tool. As so happens with many systems studies, new questions arise when attempting to answer the original hypothesis. The following questions need to be addressed:

1. Waterfowl use of the area will increase, but will total production in the unit actually increase?
2. What role does detritus play in invertebrate numbers and diversity?
3. What can be expected in the way of increased macrophyte biomass and macrophyte diversity?
4. What effect will nutrient enrichment have on the caloric content of the different plant and animal food sources?
5. What effect will nutrient enrichment have on other wetlands wildlife?
6. Once phosphorus has accumulated in the sediments, will natural cycling provide sufficient quantities to maintain the desired level of productivity?
7. What effect, if any, will fertilization have on downstream environments?

LITERATURE CITED

Beard, E. B. 1953. The importance of beaver in waterfowl management at the Seney National Wildlife Refuge. J. Wildl. Manage. 17(4): 398-436

Boyd, C. E., and L. W. Hess, 1970. Factors influencing shoot production and mineral nutrient levels in Typha latifolia. Ecology, 51: 285-290.

Boyd, C. E. 1981. Comparison of five fertilization programs for fish ponds. Tran. Am. Fish. Soci. 110: 541-545.

Canada Land Inventory, 1970. Land capability for wildlife-waterfowl. Dept. of Regional Economic Expansion. Queens Printer, Ottawa.

Cross, P. M., and F. H. Rigler, 1983. Phosphorus and iron retention in sediments measured by mass budget calculations and directly. Can. J. Fish. Aquat. Sci. 40: 1589-1596.

Cummins, K. W., 1973. Trophic relations of aquatic insects. Annu. Rev. Entomol. 18: 183-206.

Davis, C. B., and A. G. van der Volk, 1983. Uptake and release of nutrient by living and decomposing Typha glauca Godr. tissues at Eagle Lake, Iowa. Aquat. Bot. 16: 75-89.

Findlay, D. L., and S. E. M. Kasian, 1987. Phytoplankton community responses to nutrient addition in Lake 226, Experimental Lakes Area, northwestern Ontario. Can. J. Fish. Aquat. Sci. 44 (Suppl. 1): 35-46.

Fraser, J. E., and D. L. Britt, 1982. Liming of acidified waters: a review of methods and effects on aquatic ecosystems. U.S. Fish and Wildlife Service, Division of Biological Services, Eastern Energy and Land Use Team, FWS/OBS-80/40.13, 189pp.

Goulder, R., 1969. Interactions between the rates of production of a freshwater macrophyte and phytoplankton in a pond. OIKOS 20(2): 300-309.

Hasler, A. D., and E. Jones, 1949. Demonstration of the antagonistic action of large aquatic plants on algae and rotifers. Ecology 30: 359-364.

Hesslein, R. H., 1976. An in situ sampler for close interval pore water studies. Limnol. Oceanogr. 21: 912-914.

Hohman, W. L., 1985. Feeding ecology of ring-necked ducks in northwestern Minnesota. J. Wildl. Manage. 49(3): 546-557.

Holm, E. R., and M. L. Scott, 1954. Studies on the nutrition of wild waterfowl. New York Fish and Game Journal. 1(2): 171-178.

Joyner, D. E., 1980. Influence of invertebrates on pond selection by ducks in Ontario. J. Wildl. Manage. 44(37): 700-705.

Kaminski, R. M., and H. H. Prince, 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. J. Wildl. Manage. 45(1): 1-15.

Kerekes, J., B. Freedman, G. Howell, and P. Clifford, 1984. Comparison of the characteristics of an acidic eutrophic, and an acidic oligotrophic lake near Halifax, Nova Scotia. Water Poll. Res. J. Canada. 19(1): 1-10.

Krapu, G. L., 1974. Foods of breeding pintails in North America. J. Wildl. Manage. 38(3): 408-417.

Krapu, G. L., and G. A. Swenson, 1975. Some nutritional aspects of reproduction in prairie nesting pintails. J. Wildl. Manage. 39: 156-162.

Krapu, G. L., 1981. The role of nutrient reserves in mallard production. Auk. 98: 29-38.

Krull, J. N., 1970. Aquatic plant - macroinvertebrate associations and waterfowl. J. Wildl. Manage. 34(4): 707-718.

Landers, J. L., T. T. Fendley, and A. S. Johnson, 1977. Feeding ecology of wood ducks in South Carolina. J. Wildl. Manage. 41(1): 118-127.

Lee, G. F., 1970. Eutrophication. Northeast Fish and Wildlife Conference. pp. 39-60.

Lee, P. F. 1986. The aquaculture of wild rice, Lakehead University, Thunder Bay, Ontario. 42pp.

Levine, S. W., M. P. Stainton, and D. W. Schindler, 1986. A radiotracer study of phosphorus cycling in a eutrophic canadian shield lake, Lake 227, northwestern Ontario. Can. J. Fish Aquat. Sci. 43: 366-378.

Merritt, R. W., and K. W. Cummins, 1984. An introduction to the aquatic insects of North America. Second edition. Kendall/Hunt Publishing Comp., Iowa. 722pp.

Mills, K. H., and S. M. Chalanchuk. Population dynamics of lake whitefish (Coregonus clupeaformis) during and after the fertilization of Lake 226, the Experimental Lakes Area. Can. J. Fish. Aquat. Sci. 44(suppl. 1): 55-63.

Neely, R. K. and C. B. Davis, 1985. Nitrogen and phosphorus fertilization of Sparganium eurycarpum Engelm. and Typha glauca Godr. stands. 1. Emergent plant production. Aquat. Bot. 22: 347-361.

Nilsson, L., 1978. Breeding waterfowl in eutrophicated lakes in south Sweden. Wildfowl. 29: 101-110.

Payne, F. J., R. J. Melanson and G. R. Boyd, 1984. A summary of a preliminary study in whole lake fertilization. Wildlife Division, N.S. Dept. of Lands and Forests, Kentville. 15pp.

Pennak, R. W., 1978. Fresh-water invertebrates of the United States. Second edition. John Wiley and Sons, New York. 803pp.

Perrin, C. J., M. L. Bothwell, and P. A. Slaney, 1987. Experimental enrichment of a coastal stream in British Columbia: effects of organic and inorganic additions on autotrophic periphyton production. Can. J. Fish. Aquat. Sci. 44 (suppl. 1): 1247-1256.

Planas, D., F. Sarhan, L. Dube, H. Godmaire and C. Cadieux, 1980. Ecological significance of phenolic compounds of Myriophyllum spicatum. 21st Congress of the International Society of Limnology, Kyoto, Japan. Part Three: 1492-1496.

Reinecke, K. J., 1977. The importance of freshwater invertebrates and female energy reserves for black ducks breeding in Maine. Ph.D. thesis, Univ. of Maine, Orono. 133pp.

Reinecke, K. J., 1979. Feeding ecology and development of juvenile black ducks in Maine. Auk 96: 737-745.

Reinecke, K. J., and R. B. Owen, Jr., 1980. Food use and nutrition of black ducks nesting in Maine. J. Wildl. Manage. 44(3): 549-558.

Ross, P. E., P. Chow, and H. C. Duthie, 1979. Changes in phytoplankton and phytoplankton-zooplankton relationships following fertilization of Lower Baie Philippe, Lake Matamek. A preliminary report on studies in 1978. Woods Hole Tech. Report. WHO1-79-49. 63-69.

Schindler, D. W., R. H. Hesslein, and M. A. Turner, 1987. Exchange of nutrients between sediments and water after 15 years of experimental eutrophication. Can. J. Fish. Aquat. Sci. 44(suppl. 1): 26-33.

Shearer, J. A., E. J. Fee, E. R. DeBruyn, and D. R. DeClercq, 1987. Phytoplankton productivity changes in a small, double-basin lake in response to termination of experimental fertilization. Can. J. Fish. Aquat. Sci. 44(suppl. 1): 47-54.

Simmons, M., D. Davis, L. Griffiths and A. Muecke, 1984. Natural History of Nova Scotia. N. S. Dept. of Education and N. S. Dept. of Lands and Forests, Halifax. 2 Vols, 807pp.

Smith, M. W., 1969. Changes in environment and biota of a natural lake after fertilization. J. Fish. Res. Bb. Can. 26(12): 3101-3132.

Strong, K. W., 1987. The effect of lime on the zooplankton population of Sandy Lake, Halifax County, Nova Scotia. Proc. N. S. Inst. Sci. Vol. 37: 63-70.

Sugden, L. G. 1973. Feeding ecology of pintail, gadwall, american widgeon and lesser scaup ducklings in southern Alberta. Can. Wildl. Serv. Rep. Ser. No. 24.

Swanson, G. A., and M. I. Meyer, 1973. The role of invertebrates in the feeding ecology of Anatinae during the breeding season. Proc. Waterfowl Habitat Manage. Symp. Wildl. Manage. Inst., Washington. 32 pp.

Wetzel, R. G., 1983. Limnology. Second Edition. Saunders College Publishing. New York. 767 pp.

Whitman, W. R. 1974. The response of macroinvertebrates to experimental marsh management. Phd. thesis presented to University of Maine at Orono. 114 pp.

TABLES

Table 1. Physical Characteristics of Jordan Lake.

Area ha.	Watershed ha.	Mean Depth	Max. Depth	Soil Type	Shoreline (m)	Volume
1,267	6,478	1.3 m	3.1 m	Halifax/ organic	45,828	16,650,000m^3

Table 2. Chemical Characteristics of Jordan Lake: July 19, 1984

pH	Alkalinity mg/l	Hardness mg/l	Cond. mmho/cm	Color T.C.U.	Total P mg/l	Nitrate & Nitrite mg/l
5.6	2.4	3.984	28.0	35.0	0.007	0.060

Table 3. Fauna of Jordan Lake.

Fish	White Sucker (*Catostomus commersoni*), Brown bullhead (*Ictalurus nebulosus*), White Perch (*Morone americana*), Yellow Perch (*Perca flavescens*), Brook Trout (*Salvelinus fontinalis*), Nine-spine Stickleback (*Pungitius pungitius*), Banded Killifish (*Fundulus diaphanus*), Golden Shiner (*Notemigonus crysoleucas*).
Mammal	Otter (*Lontra canadensis*), Muskrat (*Ondatra zibethicus*), Beaver (*Castor canadensis*), Mink (*Mustela vison*).
Amphibian	Green Frog (*Rana clamitans melanota*), Bullfrog (*Rana catesbeiana*), Wood Frog (*Rana sylvatica*), Northern Spring Peepers (*Hyla crucifer crucifer*), Red-spotted Newt (*Notophthalmus viridescens viridescens*).
Reptiles	Eastern Painted Turtle (*Chrysemys picta picta*), Common Snapping Turtle (*Chelydra serpentina serpentina*).
Waterfowl	American Black Duck (*Anas rubripes*), Wood Duck (*Aix sponsa*), Ring-necked Duck (*Aythya collaris*), American Widgeon (*Anas americana*), Hooded Merganser (*Mergus cucullatus*), Common Merganser (*Mergus merganser americanus*).

Table 4. Flora of East Bay.

EMERGENT

Sedge (*Carex sp.*)
Leatherleaf (*Chamaedaphne calyculata*)
Sundew (*Drosera rotundifolia*)
Three Way Sedge (*Dulichium arundinaceum*)
Spike Rush (*Eleocharis acicularis*)
Manna Grass (*Glyceria sp.*)
Glyceria sp.
Saint Johns Wort (*Hypericum sp.*)
Juncus canadensis
Military rush (*Juncus militaris*)
Labrador-Tea (*Ledum groenlandicum*)
Sweet Gale (*Myrica gale*)
Pickerel Weed (*Pontederia cordata*)
Slender Arrow-Head (*Sagittaria graminea*)
Common Arrow-Head (*Sagittaria latifolia*
Picture Plant (*Sarracenia purpurea*)
Woolgrass (*Scirpus sp.*)
Eastern Bur-reed (*Sparganium americanum*)
Floating Bur-reed (*Sparganium fluctuans*)
Sphagnum sp.
Hardhack (*Spiraea latifolia*)
Cranberry (*Viburnum trilobum*)

FLOATING

Water Shield (*Brasenia schreberi*)
Yellow Water Lily (*Nuphar variegatum*)
White Water Lily (*Nymphaea odorata*)
Floating Heart (*Nymphoides cordata*)
Oakes Pondweed (*Potamogeton oakesianus*)

SUBMERGENT

Algae
Alga Pondweed (*Potamogeton confervoides*)
Sphagnum
Sphagnum macrophyllum
Bladderwort (*Utricularia sp.*)

Table 5. Water Sample Dates

Year	Month	Day
1984	April	26
	May	17, 28
	June	13
	July	26
	August	8, 23
1985	April	28
	May	15, 16, 17, 18, 19, 20
	June	4, 5, 6, 11, 12, 25, 26
	July	3, 4, 11, 16, 17, 22, 23
	August	14, 20
	October	10
1986	April	24
	May	6, 8, 20
	June	5, 18, 20
	July	22
	August	15
	September	30
	November	14
1987	April	28
	May	14, 21
	June	7, 17
	July	9, 22
	August	12
	September	1
	November	5

Table No. 6: Statistical analysis of water chemistry for samples taken April through August in 1984 through 1987.

Hardness (mg/l $CaCo_3$)

Experimental Area

Year	1984	1985	1986	1987
Monthly	3.8	25.3	7.5	6.2
Means (Y)	5.6	21.6	9.8	7.0
	4.2	24.8	10.7	9.5
	4.3	23.6	15.6	9.1
	-	18.2	11.1	10.2
ΣY	17.9	113.5	54.7	42.0
$\bar{Y}$	4.5	22.7	10.9	8.4
N	4	5	5	5
D. F.	3	4	4	4
S. D.	.78	2.89	2.95	1.71
S. S^2	81.93	2609.89	633.35	364.54
S^2	.61	8.36	8.73	2.94

Control Area

Year	1984	1985	1986	1987
Monthly	3.7	4.7	4.1	3.1
Means (Y)	3.7	4.6	4.3	3.2
	3.9	4.9	3.7	3.7
	4.5	5.3	7.9	5.9
	-	4.7	4.1	4.2
ΣY	15.8	24.2	24.1	20.1
$\bar{Y}$	4.0	4.8	4.8	4.0
N	4	5	5	5
D. F.	3	4	4	4
S. D.	.38	.28	1.74	1.14
S. S^2	62.84	117.44	128.21	85.99
S^2	.14	.08	3.01	1.30

F Values

Experimental x Control: 84=4.25 85=107.171** 86=2.900 87=2.263

T Values

Experimental: 84 x 85=13.493** 84 x 86=4.692** 84 x 87=4.565** 85 x 86=6.360** 85 x 87=9.514** 86 x 87=1.663

Control: 84 x 85=3.924** 84 x 86=1.089 84 x 87=.129 85 x 86=.011 85 x 87=1.564 86 x 87=.862

Experimental x Control: 84=1.210 85=13.748** 86=3.993** 87=4.761**

* = Significant at 95% level
** = Significant at 99% level

Table No. 6 (Con'd.):

Alkalinity (mg/l $CaCO_3$)

Experimental Area

Year	1984	1985	1986	1987
Monthly	1.4	20.0	5.3	5.3
Means(Y)	1.0	17.5	5.4	4.4
	1.0	20.6	9.0	6.5
	2.4	18.5	12.3	6.2
	1.0	14.0	6.3	6.5
ΣY	6.8	90.6	38.3	28.9
$\bar{Y}$	1.36	18.12	7.66	5.78
N	5	5	5	5
D.F.	4	4	4	4
S.D.	.61	2.61	2.99	.91
S.S.	10.72	1668.86	329.23	170.39
S^2	.37	6.80	8.96	.84

Control Area

Year	1984	1985	1986	1987
Monthly	1.0	1.1	1.7	2.0
Means (Y)	1.0	1.1	1.2	1.0
	1.0	1.8	3.1	2.2
	2.3	1.6	5.1	5.2
	2.0	1.3	1.0	1.6
ΣY	7.0	6.9	12.1	12.0
$\bar{Y}$	1.46	1.38	2.42	2.4
N	5	5	5	5
D.F.	4	4	4	4
S.D.	.64	.31	1.71	1.63
S.S.	12.29	9.91	40.95	39.44
S^2	.41	.10	2.92	2.66

F Values

Experimental x Control: 84=1.109 85=70.094** 86=3.073
87=3.178

T Values

Experimental: 84 x 85=14.001** 84 x 86=4.612** 84 x 87=9.004**
85 x 86=5.892** 85 x 87=9.897** 86 x 87=1.343

Control: 84 x 85=.252 84 x 86=1.177 84 x 87=1.200
85 x 86=1.340 85 x 87=1.374 86 x 87=.019

Experimental x Control: 84=.253 85=14.256** 86=3.399**
87=4.042**

Table No. 6 (Cont'd.):

Conductivity (MICROMHO/CM)

Experimental Area

Year	1984	1985	1986	1987
Monthly	25.0	67.0	31.4	24.3
Means (Y)	25.0	66.5	36.6	27.2
	22.0	64.9	35.7	28.6
	27.2	55.7	35.0	22.7
	27.5	38.5	30.8	22.2
ΣY	126.7	292.6	169.5	125.0
$\bar{Y}$	25.34	58.52	33.9	25.0
N	5	5	5	5
D. F.	4	4	4	4
S. D.	2.21	12.09	2.63	2.80
S. S.	3230.09	17708.0	5773.65	3156.42
S^2	4.88	146.26	6.90	7.86

Control Area

Year	1984	1985	1986	1987
Monthly	25.0	29.6	27.0	21.0
Means (Y)	25.5	28.8	27.5	23.0
	27.0	29.2	26.3	24.0
	28.0	28.6	36.0	29.8
	31.6	24.0	27.1	25.8
ΣY	137.1	140.2	143.9	123.6
$\bar{Y}$	27.42	28.04	28.78	24.72
N	5	5	5	5
D. F.	4	4	4	4
S. D.	2.62	2.29	4.06	3.33
S. S.	3786.81	3952.2	4207.35	3099.68
S^2	6.88	5.25	16.48	11.07

F Values

Experimental x Control: 84=1.411 85=27.870** 86=2.388 87=1.410

T Values

Experimental: 84 x 85=6.033** 84 x 86=5.577** 84 x 87=.414
85 x 86=4.448** 85 x 87=6.038** 86 x 87=5.181**

Control: 84 x 85=.391 84 x 86=.629 84 x 87=1.425
85 x 86=.355 85 x 87=1.838 86 x 87=1.730

Experimental x Control: 84=1.356 85=5.537** 86=2.368* 87=.144

Table No. 6 (Cont'd.):

pH (natural log)

Experimental Area

Year	1984	1985	1986	1987
Monthly	200.3	1096.6	492.7	601.8
Means (Y)	200.3	992.3	445.9	445.1
	221.4	897.8	544.6	330.3
	200.3	665.1	365.0	365.0
	181.3	544.6	665.0	365.0
ΣY	1003.6	4196.4	2213.2	2107.2
$\bar{Y}$	200.72	839.28	442.64	421.44
N	5	5	5	5
D.F.	4	4	4	4
S.D.	14.19	229.25	79.0	109.28
S.S.^{2}	202247.92	3732182.86	1004619.26	935825.34
S^2	201.33	52555.56	6241.0	11942.12

Control Area

Year	1984	1985	1986	1987
Monthly	164.0	224.7	224.7	224.7
Means (Y)	164.0	200.3	221.4	200.3
	181.3	200.3	220.3	200.3
	164.0	221.4	200.3	298.9
	200.3	200.3	200.3	298.9
ΣY	873.6	1067.0	1067.0	1243.1
$\bar{Y}$	174.72	213.4	213.4	248.6
N	5	5	5	5
D.F.	4	4	4	4
S.D.	16.14	19.74	19.74	49.35
S.S.^{2}	153677.78	229256.32	229256.32	318800.69
S^2	260.60	389.63	389.63	2435.32

F Values

Experimental x Control: 84=1.294 85=134.886** 86=16.018** 87=4.904

T Values

Experimental: 84 x 85=6.217** 84 x 86=6.740** 84 x 87=4.479** 85 x 86=3.658** 85 x 87=3.679** 86 x 87=.352

Control: 84 x 85=3.392** 84 x 86=3.392** 84 x 87=3.182* 85 x 86=0.000 85 x 87=1.566 86 x 87=1.566

Experimental x Control: 84=2.705* 85=6.082** 86=6.295** 87=3.223*

Table No. 6 (Cont'd.):

Total Phosphorus (mg/l)

Experimental Area

Year	1984	1985	1986	1987
Monthly	.005	.006	.013	.029
Means (Y)	.007	.702	.742	.430
	.010	.178	.172	.278
	.013	.151	.088	.153
	.021	.079	.056	.224
ΣY	.056	1.116	1.071	1.114
$\bar{Y}$	.011	.223	.214	.224
N	5	5	5	5
D.F.	4	4	4	4
S. D.	.006	.276	.301	.149
S. S^2	.0008	.5540	.5910	.3370
S^2	.00004	.07612	.09045	.02210

Control Area

Year	1984	1985	1986	1987
Monthly	.003	.006	.005	.008
Means (Y)	.006	.006	.010	.007
	.011	.008	.008	.006
	.012	.007	.022	.022
	.020	.009	.008	.008
ΣY	.052	.036	.053	.051
$\bar{Y}$	.010	.007	.011	.010
N	5	5	5	5
D. F.	4	4	4	4
S. D.	.007	.001	.007	.007
S. S^2	.0007	.0003	.0007	.0007
S^2	.00005	.000001	.00005	.00005

F Values

Experimental x Control: 84=1.361 85=76176.0** 86=1849.0** 87=453.1**

T Values

Experimental: 84 x 85=1.715 84 x 86=1.507 84 x 87=3.198* 85 x 86=.049 85 x 87=.007 86 x 87=.067

Control: 84 x 85=1.012 84 x 86=.045 84 x 87= .045 85 x 86=.303 85 x 87=.949 86 x 87=.090

Experimental x Control: 84=.191 85=1.749 86=1.512 87=3.212*

Table No. 6 (Cont'd.):

Total Nitrogen (mg/l)

Experimental Area

Year	1984	1985	1986	1987
Monthly	.200	.380	.360	.430
Means (Y)	.245	7.571	.453	1.385
	.405	1.530	1.912	.833
	.475	1.290	.790	1.095
	.570	.815	.510	.900
ΣY	1.895	11.586	4.025	4.643
$\bar{Y}$	.379	3.317	.805	.929
N	5	5	5	5
D. F.	4	4	4	4
S. D.	.155	2.970	.639	.352
S. S^2	.815	62.134	4.875	4.806
S^2	.024	8.821	.409	.124

Control Area

Year	1984	1985	1986	1987
Monthly	.205	.260	.210	.250
Means (Y)	.270	.242	.243	.280
	.430	.358	.327	.302
	.660	.374	.500	.850
	.730	.310	.300	.440
ΣY	2.295	1.544	1.580	2.122
$\bar{Y}$	.459	.309	.316	.424
N	5	5	5	5
D. F.	4	4	4	4
S. D.	.232	.058	.113	.249
S. S^2	1.268	.490	.550	1.148
S^2	.054	.003	.013	.062

F Values

Experimental x Control: 84=2.231 85=2613.802** 86=32.179** 87=1.997

T Values

Experimental: 84 x 85=2.209 84 x 86=1.448 84 x 87=3.198* 85 x 86=1.849 85 x 87=2.389 86 x 87=.379

Control: 84 x 85=1.405 84 x 86=1.241 84 x 87=.228 85 x 86=.127 85 x 87=1.012 86 x 87=.887

Experimental x Control: 84=.601 85=2.264 86=1.684 87=2.618*

Table No. 7. Pre and post fertilization water chemistry.

	Phosphorus Level in mg/l						
Year	Pre Fertilization*	Post Fertilization**					
1985	0.006	1.705	1.340	0.975	0.535	0.340	0.050
Day	1	2	3	4	5	6	21
		0.066	0.052	0.041	0.062		
		22	23	28	29		

* May 14

** May 15 through June 11. On day 2 750 kg of the fertilizer mix (10 parts nitrogen/1 part phosphorus) was dissolved in 3200 litres of water and sprayed over the marsh. On June 5 (day 23) 275 kg of the fertilizer mix was added to eleven bags and hung throughout the marsh.

Table No. 8. Average monthly water chemistry levels, 1984 through 1987.

Experimental Area

Month	APRIL				MAY				JUNE			
Number of Samples	1	1	1	1	2	6	3	2	1	7	3	2
Hardness ($CaCo_3$)	3.8	25.3	7.5	6.2	5.6	21.6	9.8	7.0	4.2	24.8	10.7	9.5
Alkalinity ($CaCo_3$)	1.4	20.0	5.3	5.3	<1.0	17.5	5.4	4.4	<1.0	20.6	9.0	6.5
Conductivity (Mmho/cm)	25.0	67.0	31.4	24.3	25.0	66.5	36.6	27.2	22.0	64.9	35.7	28.6
pH	5.3	7.0	6.2	6.4	5.3	6.9	6.1	6.1	5.4	6.8	6.3	5.8
Total Phosphorus (mg/1)	.005	.006	.013	.029	.007	.702	.742	.430	.010	.178	.172	.278
Total Nitrogen (mg/1)	.200	.380	.36	.430	.245	7.571	.453	1.385	.405	1.53	1.912	.833
Chlorophyll "a" (mg/m^3)	-	1.0	-	-	-	2.4	2.4	-	-	5.76	4.4	-
Year	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
Month	JULY				AUGUST				SEPTEMBER			
Number of Samples	1	7	1	2	2	2	1	1	-	-	1	1
Hardness ($CaCo_3$)	4.3	23.6	15.6	9.1	-	18.2	11.1	10.2	-	-	8.5	12.0
Alkalinity ($CaCo_3$)	2.4	18.5	12.3	6.2	1.0	14.0	6.3	6.5	-	-	6.0	8.3
Conductivity (Mmho/cm)	27.2	55.7	35.0	22.7	27.5	38.5	30.8	22.2	-	-	27.6	24.0
pH	5.3	6.5	5.9	5.9	5.2	6.3	5.9	5.9	-	-	6.3	6.4
Total Phosphorus (mg/1)	.013	.151	.088	.153	.021	.079	.056	.224	-	-	.060	.050
Total Nitrogen	.475	1.29	.790	1.095	.570	.815	.510	.900	-	-	.63	.740
Chlorophyll "a" (mg/m^3)	-	3.9	14.9	-	2.4	.50	5.4	-	-	-	4.0	
Year	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987

Table No. 8. (cont'd.)

Experimental Area (cont'd.)

Month	OCTOBER				NOVEMBER			
Number of Samples	-	1	-	-	-	-	1	1
Hardness ($CaCo_3$)	-	19.2	-	-	-	-	9.0	10.4
Alkalinity ($CaCo_3$)	-	15.5	-	-	-	-	4.9	7.0
Conductivity (Mmho/cm)	-	47.3	-	-	-	-	30.7	31.0
pH	-	6.8	-	-	-	-	6.0	6.6
Total Phosphorus (mg/1)	-	.033	-	-	-	-	.045	.045
Total Nitrogen (mg/1)	-	.580	-	-	-	-	.715	0.71
Chlorophyll "a" (mg/m^3)	-	1.9	-	-	-	-	4.0	-
Year	1984	1985	1986	1987	1984	1985	1986	1987

Table No. 8 (cont'd.)

Control

Month	APRIL				MAY				JUNE			
Number of Samples	1	1	1	1	2	6	3	2	1	6	3	2
Hardness ($CaCo_3$)	3.7	4.7	4.1	3.1	3.7	4.6	4.3	3.2	3.9	4.9	3.7	3.7
Alkalinity ($CaCo_3$)	1.0	1.1	1.7	2.0	<1.0	1.1	1.2	<1.0	<1.0	1.8	3.1	2.2
Conductivity (Mmho/cm)	25.0	29.6	27.0	21.0	25.5	28.8	27.5	23.0	27.0	29.2	26.3	24.0
pH	5.1	5.5	5.5	5.5	5.1	5.3	5.4	5.3	5.2	5.3	5.3	5.3
Total Phosphorus (mg/1)	.003	.006	.005	.008	.006	.006	.010	.007	.011	.008	.008	.006
Total Nitrogen (mg/1)	.205	.260	.210	.250	.270	.242	.243	.280	.430	.358	.327	.302
Chlorophyll "a" (mg/m^3)	-	0.5	-	-	-	1.2	1.0	-	-	0.9	1.6	1.5
Year	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
Month	JULY				AUGUST				SEPTEMBER			
Number of Samples	1	7	1	1	1	2	1	1	-	-	1	-
Hardness ($CaCo_3$)	4.5	5.3	7.9	5.9	-	4.7	4.1	4.2	-	-	3.9	-
Alkalinity ($CaCo_3$)	2.3	1.6	5.1	5.2	2.0	1.3	<1.0	1.6	-	-	1.6	-
Conductivity (Mmho/cm)	28.0	28.6	36.0	29.8	31.6	24.0	27.1	25.8	-	-	27.0	-
pH	5.1	5.4	5.3	5.7	5.3	5.3	5.3	5.7	-	-	5.5	-
Total Phosphorus (mg/1)	.012	.007	.022	.022	.020	.009	.008	.008	-	-	.005	-
Total Nitrogen (mg/1)	.660	.374	.500	.850	.730	.310	.300	.440	-	-	.380	-
Chlorophyll "a" (mg/m^3)	-	0.7	2.600	-	<2.0	0.2	1.7	2.5	-	-	1.0	-
Year	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987

Table No. 8 (cont'd.)

Control (cont'd.)

Month	OCTOBER				NOVEMBER			
Number of Samples	-	1	-	-	-	-	1	1
Hardness ($CaCo_3$)	-	4.7	-	-	-	-	7.1	5.4
Alkalinity ($CaCo_3$)	-	2.0	-	-	-	-	1.9	2.5
Conductivity (Mmho/cm)	-	29.1	-	-	-	-	29.1	28.5
pH	-	5.8	-	-	-	-	5.4	5.5
Total Phosphorus (mg/1)	-	.012	-	-	-	-	.020	.010
Total Nitrogen	-	.380	-	-	-	-	.460	.460
Chlorophyll "a" (mg/m^3)	-	<.1	-	-	-	-	1.8	15.9
Year	1984	1985	1986	1987	1984	1985	1986	1987

Table 9. Average yearly water chemistry levels.

Compartment E (Experimental) Number of Samples	7	24	11	10
Hardness ($CaCo_3$)	4.5	21.4	10.3	12.8
Alkalinity ($CaCo_3$)	1.1	17.2	7.0	6.3
Conductivity (Mmho/cm)	25.4	54.6	32.6	25.7
pH	5.3	6.6	6.1	6.1
Total Phosphorus (mg/1)	.011	.228	.173	.170
Total Nitrogen (mg/1)	.379	2.357	.767	.819
Year	1984	1985	1986	1987
Compartment C (Control) Number of Samples	**7**	**24**	**11**	**8**
Hardness ($CaCo_3$)	3.95	5.4	5.0	4.3
Alkalinity ($CaCo_3$)	1.4	1.6	2.1	2.3
Conductivity (Mmho/cm)	27.4	27.9	28.6	25.4
pH	5.2	5.4	5.4	5.5
Total Phosphorus (mg/1)	0.018	.010	.011	.009
Total Nitrogen (mg/1)	0.437	.332	.337	.430
Year	1984	1985	1986	1987

Table No. 10. Pre and post liming water chemistry from the April samples*.

Year	Hardness	Alkalinity	Conductivity	pH	Total Phosphorus	Total Nitrogen
1984	4	<1	25	5.3	.005	.400
1985	22	18	62	7.0	.010	.400

* Lime was applied over the ice at the rate of one ton per acre on 15 January, 1985.

Table 11. Lake sediment analysis by year.

Parameter	E	C	E	C	E	C	E	C
Conductance (Mmho/cm)	19	22	12	12	16	<10	15	18
pH	4.7	4.5	4.3	4.3	4.7	5.1	4.5	4.6
P_2O_5 (kg/ha)	30	30	trace	trace	17	15	50	29
K_2O (kg/ha)	65	60	24	26	35	25	16	17
Ca (kg/ha)	2079	1722	821	791	1036	842	912	1005
Mg (kg/ha)	289	308	149	222	160	98	177	262
Total P (ppm)	-	-	433	440	560	352	468	450
Year	1984 Spring		1985 Spring*		1985 Fall		1986 Spring*	

Experimental = E Control = C

*The spring 1985 and 1986 samples were taken prior to the years fertilizer application.

Table 12. Analysis of lake sediment - pore water for fall of 1987 after three years of fertilization.

Depth (cm)	pH		Conductance		S R P	
	E	C	E	C	E	C
-10:-6	6.59	-	60.00	-	-	2.65
-5:-1	6.62	5.88	62.80	42.33	39.9	3.72
-0-	6.65	5.90	52.00	42.00	111.0	4.40
1-5	6.89	6.26	67.20	52.50	329.6	5.46
6-10	7.18	6.56	90.20	-	532.4	7.84
11-15	7.40	6.72	119.00	62.00	586.6	10.04
16-20	7.38	6.74	142.00	62.80	588.0	13.74
21-25	7.19	6.48	145.60	64.60	589.0	19.10
26-30	6.86	6.45	143.00	69.40	597.6	21.10
31-35	6.66	6.87	129.40	69.40	594.4	21.24
36-40	6.56	7.01	109.60	76.40	590.0	37.24
41-45	6.54	7.03	102.80	76.40	588.0	29.98
46-50	6.50	7.11	94.80	80.40	582.0	38.70
51-55	6.52	7.19	89.75	82.00	518.0	31.20
56-60	-	-	-	-	450.8	34.42
61-65	-	-	-	-	492.0	30.00

E = Experimental Area

C = Control Area

Table No. 13. Statistical analysis of total aquatic invertebrate numbers for 1984 and 1986 between the experimental and the control areas and within the experimental and the control areas.

Year	Sample Area	Significance
1984	Experimental x Control	Not Significant
1986	Experimental x Control	Significant @ 0.01%
1984-86	Control x Control	Significant @ 0.025%
1984-86	Experimental x Experimental	Significant @ 0.005%

Table 14. Total aquatic invertebrate numbers by year and order.

Experimental Area

Order	1984	% Change 84-85	1985	% Change 84-86	1986	% Change 86-87	1987
AMPHIPODA	29	-93%	2	-93%	2	-100%	0
HYDRACARINA	12	-17%	14	0%	12	+33%	16
COLEOPTERA	22	+86%	41	+64%	36	+668%	169
DIPTERA	1344	+143%	3269	+673%	10,386	+371%	6325
EPHEMEROPTERA	-	-	16	-	194	-	58
GASTROPODA	71	+82%	129	+421%	370	+1,106%	856
HEMIPTERA	35	-63%	13	+83%	64	+171%	95
HIRUNDINEA	-	-	12	-	128	-	401
ISOPODA	42	+260%	151	+426%	221	+7,324%	3118
ODONATA	193	+38%	311	+90%	366	+171%	523
PELECYPODA	68	+40%	95	-38%	42	+75%	119
TRICHOPTERA	137	-16%	113	-17%	114	+167%	366
TOTAL	1953	+113.3%	4166	+511.1%	11,935	+516.8%	12,046

Control Area

Order	1984	% Change 84-85	1985	% Change 84-86	1986
AMPHIPODA	66	-7.6%	61	+190.9%	192
HYDRACARINA	11	-63.6%	4	-9.1%	10
COLEOPTERA	26	-34.6%	17	-53.8%	12
DIPTERA	896	+101.9%	1809	+369.5%	4162
EPHEMEROPTERA	1	-	1	-	19
GASTROPODA	243	-84.4%	38	-92.6%	18
HEMIPTERA	82	-20.7%	65	-43.9%	46
HIRUNDINEA	-	-	1	-	8
ISOPODA	53	+3.8%	55	-37.7%	33
ODONATA	349	-23.8%	266	-13.2%	303
PELECYPODA	175	-11.4%	155	-78.3%	38
TRICHOPTERA	107	+112.1%	227	+73.8%	186
TOTAL	2009	34.3%	2699	150.2%	5027
TOTAL MINUS DIPTERANS	1113	-20.0%	890	-22.33%	865

Table No. 15. Aquatic invertebrate trophic levels by rank and year.

Feeding Category	Experimental Area		Control Area	
	1984	1986	1984	1986
Collector (herb./detr.)	1	1	1	1
Predator (swallower)	2	2	2	2
Shredder (detritivore)	3	4	4	3
Scraper (organic)	4	3	3	7
Predator (piercer)	5	5	5	4
Shredder (herbivore)	6	7	6	5
Collector (detritivore)	-	6	8	6
Scraper (mineral)	-	8	7	8

1 = greatest number of individuals
8 = least number of individuals

Table No. 16. Comparison of aquatic invertebrates (trophic relationship) between the Control (C) and Experimental (E) Areas for 1984 and 1986.

	% of Total				% Change	
	1984	1986	1984	1986	1984-86	1984-86
Feeding Relationship	E	E	C	C	E-E	C-C
Shredder (herbivore)	1.07	0.44	1.15	0.64	-0.63	-0.51
Shredder (detritivore)	5.63	1.89	7.22	4.79	-3.74	-2.43
Collector (herb./detr.)	63.75	81.39	45.35	68.15	+17.64	+22.80
Collector (detritivore)	___	1.63	0.05	0.38	+1.63	+0.33
Scraper (organic)	3.64	3.10	12.10	0.36	-0.54	-11.74
Scraper (mineral)	___	0.03	0.10	___	+0.03	-0.10
Predator (swallower)	23.50	9.81	29.42	24.41	-13.69	-5.01
Predator (piercer)	2.41	1.71	4.63	1.27	-0.70	-3.36
	100.00	100.00	100.02	100.00		

Table No. 17. Dry and ashless weights for aquatic invertebrate for 1984, 1986 and 1987.

Compartment	% Ashless Wt. of Dry Wt. (gms)			Total Yearly Dry Wt. (gms)			Total Yearly Ashless Wt. (gms)		
	1984	1986	1987	1984	1986	1987	1984	1986	1987
E	81.3	65.8	53.4	3.996	8.060	8.672	3.248	5.304	4.628
C	87.4	74.1	72.6	4.808	3.524		4.200	2.61	

E = Experimental Area

C = Control Area

Table No. 18. Nest box results for East Bay, the experimental and control area.

Box No.	1984	1985	1986	1987	No. Times Used
S-1	X	X	X	X	4
S-2	O	O	X	X	2
S-3	X	X	X	X	4
S-4	X	X	X	X	4
S-5	X	X	X	X	4
S-6	X	O	X	X	3
S-7	X	O	X	X	3
Total Used	6	4	7	7	24
W-1	O	X(W)	O	O	1
W-2	O	O	X(M)	O	1
W-3	O	O	O	X(W)	1
W-4	O	O	X(W)	O	1
W-5	O	X(M)	O	O	1
W-6	O	O	X(M)	O	1
W-7	O	O	O	O	0
W-8	O	O	O	O	0
W-9			X(M)	O	1
W-10			O	O	0
W-11			O	X(W)	1
W-12			O	O	0
W-13			O	X(W)	1
W-14			O	*	0
W-15			X(W)	O	1
W-16			O	X(M)	1
W-17			O	O	0
W-18	_	_	O	O	0
Total Used	0	2	5	4	11

S = Swallow Box W = Duck Box O = Not Used X = Used

S-1 to S-4 in Experimental Area S-5 to S-7 in Control Area
W-1 to W-4 in Experimental Area W-5 to W-8 in Control Area
W-9 to W-18 in East Bay

(W) = Wood Duck (M) = Hooded Merganser

* W-14 was destroyed in the winter of 1986.

Table No. 19. Jordan Lake breeding bird surveys.

	1985 (End April)			1986 (First May)			1987 (End April)		
	Single	Pair	Flock	Single	Pair	Flock	Single	Pair	Flock
East Bay									
Black Ducks	2	6	0	0	1	3	0	0	0
Ring-necked Ducks	7	2	0	0	0	0	0	0	0
Hooded Merganser	0	0	0	0	0	0	0	1	0
Green-winged Teal	1	0	0	0	0	0	0	0	0
Wood Duck	0	0	0	0	0	0	0	0	0
Common Mergansers	0	0	0	0	0	0	0	1	0
	10	8	0	0	1	3	0	2	0
Experimental Area									
Black Ducks	0	1	0	2	1	0	0	1	6
Ring-necked Ducks	0	0	0	0	3	5	3	5	9
Hooded Merganser	0	0	0	0	0	0	0	0	0
Green-winged Teal	0	0	0	0	1	0	0	0	0
Wood Ducks	0	0	0	0	0	0	0	0	4
	0	1	0	2	5	5	3	6	19
Control Area									
Black Ducks	0	1	0	2	0	0	1	0	0
Ring-necked Ducks	0	0	0	0	0	0	0	0	0
Hooded Merganser	0	1	0	0	0	0	0	0	0
Green-winged Teal	0	0	0	0	0	0	0	0	0
Wood Ducks	0	1	0	1	0	0	0	0	0
	0	3	0	3	0	0	1	0	0
Grand Total	10	12	0	5	6	8	4	8	19

Table No. 20. Jordan Lake brood data 1984-87.

	1984	1985	1986	1987	
East Bay					
Black Ducks	3	5	3	3	Surveys in 1984, 1985 and 1986
Hooded Mergansers	0	0	1	0	were a combination of helicopter
Ring-necked Ducks	1	1	1	0	and ground surveys while the 1987
Wood Ducks	0	3	1	1	surveys were strictly ground
Unknown	0	0	0	0	surveys.
Total	4	9	6	4	
Experimental Area					
Black Ducks	0	1	0	1	*Halfways through the summer of 1987
Hooded Mergansers	1	1	1	2	the water level in the control area
Ring-necked Ducks	0	0	2	2	dropped to such an extent that the
Wood Ducks	0	0	0	1	area was not suitable for brood
Unknown	0	0	1	1	production.
Total	1	2	4	7	
Control Area					
Black Ducks	1	3	0	0	
Hooded Mergansers	0	0	0	0	
Ring-necked Ducks	1	0	0	0	
Wood Ducks	0	1	0	0	
Unknown	0	1	0	0	
Total	2	5	0	0*	
Grand Total	7	16	10	11	

Table No. 21. Timed wildlife observations.

Species	E		C	
	1984	1987	1984	1987
Black Duck	3	2	9	-
Wood Duck	1	3	1	2
Ring-necked Duck	7	-	2	-
Mallard	-	1	-	-
Hooded Merganser	-	3	2	1
Duck Unk.	-	-	1	-
American Bittern	-	-	1	-
Common Tern	-	1	2	-
Common Snipe	3	1	4	2
Black-backed Gull	4	-	2	1
Great Blue Heron	5	1	2	-
Common Loon	1	1	1	-
Belted Kingfisher	1	-	1	-
Red-winged Blackbird	10	4	10	3
Common Grackle	2	3	-	-
Tree Swallow	10	3	10	3
Chimney Swift	1	-	-	-
Marsh Hawk	-	-	2	-
Kestrel	-	-	1	-
Eastern Kingbird	3	1	5	1
Swamp Sparrow	-	4	2	-
Common Crow	3	-	2	-
Robin	2	-	1	2
Rusty Blackbird	-	2	-	-
Nighthawk	-	1	-	-
Song Sparrow	-	1	-	-
Total No. Observations	56	32	61	15
	14	4	12	4

	E		C	
	1984	1987	1984	1987
Number of observations	14	4	12	4
Average length of observations (min.)	40.5	30	38.8	30
Average number of sp. per observation	4	8	5.1	3.8

E = Experimental area

C = Control area

Table 22. Vegetative transect for the experimental area.

Species	Number of Occurrences 1984	1987	% of Occurrence 1984	1987	Ranking by Occurrence 1984	1987	% of Occurrence 1984	1987
Calamagrostis canadensis	-	3	-	1.92	-	15.5	-	11
Carex sp.	6	6	6.98	3.85	6.5	10	22	22
Chamaedaphne calyculata	7	9	8.14	5.77	5.8	8	26	33
Dulichium arundinaceum	17	16	19.77	10.26	1	2	63	59
Eriophorum sp.	-	1	-	0.64	-	22	-	4
Hypericaceae sp.	-	3	-	1.92	-	15.5	-	11
Juncus canadensis	2	1	2.33	0.64	11.5	22	7	4
Juncus militaris	-	1	-	0.64	-	22	-	4
Myrica gale	11	11	12.79	7.05	3	6	41	41
Pontederia cordata	6	11	6.98	7.05	6.5	6	22	41
Osmunda regalis	3	2	3.49	1.28	9.5	18.5	11	7
Sarracenia purpurea	3	1	3.49	0.64	9.5	22	11	4
Scirpus cyperinus	1	2	1.16	1.28	14.5	18.5	4	7
Sparganium americanum	4	6	4.65	3.85	8	10	15	22
Spagnum sp.	2	4	2.33	2.56	11.5	13	7	15
Viburnum trilobum	1	5	1.16	3.21	14.5	12	4	19
Lemna minor*	-	11	-	7.05	-	6	-	41
Nymphae odorata	9	15	10.47	9.62	4	3	33	56
Nuphar variegatum	1	1	1.16	0.64	14.5	22	4	4
Potamogeton epihydrus	-	6	-	3.85	-	10	-	22
Sparganium fluctuans	12	13	13.95	8.33	2	4	44	48
Elodea canadensis*	-	22	-	14.10	-	1	-	82
Myriophyllum sp.	-	3	-	1.92	-	15.5	-	11
Potamogeton confervoides	1	3	1.16	1.92	14.5	15.5	14	11
Total	86	156	100.01	99.99				
Number of Different Species	16	24						

Length of Transect = 226.8m
Number of Different Vegetative Types = 27
Average Length of Vegetative Type = 8.4m
Average Number of Species per Meter 1984 = 0.379 sp/m
Average Number of Species per Meter 1987 = 0.692 sp/m
Species per Meter Change (1984 to 1987) = +82.6%

Introduced Species Present = 3
Introduced Species Occurrence per Meter = 0.159 sp/m

Average Number of Species per Vegetative Type:
1984 = 3.2 1987 = 5.8
*Introduced Species

F I G U R E S

Figure 1. Map of Nova Scotia showing the Tobeatic Wildlife Management Area.

TOBEATIC WILDLIFE MANAGEMENT AREA

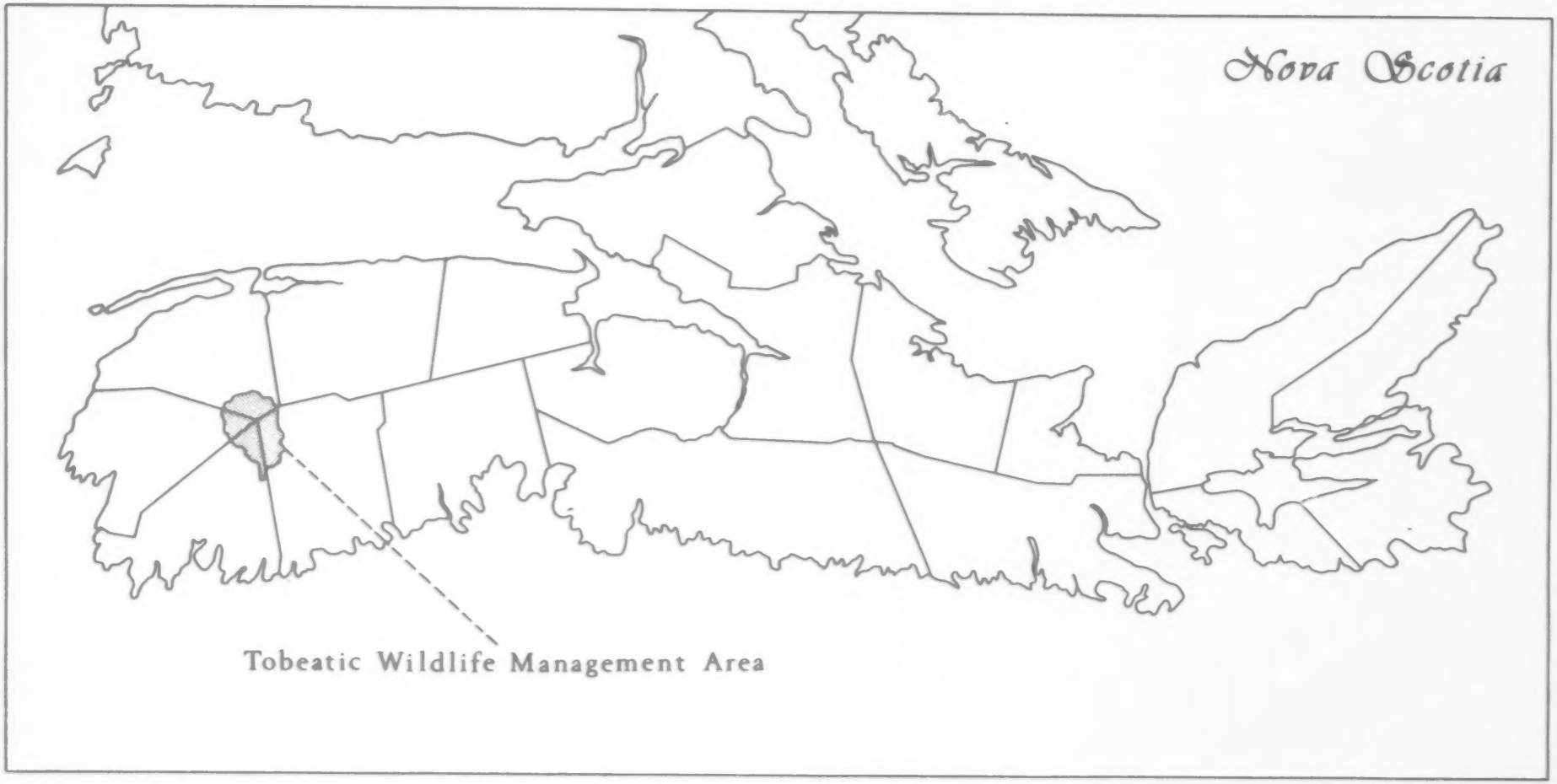


Figure 2. Study location map of Jordan Lake and Black Duck Lake.

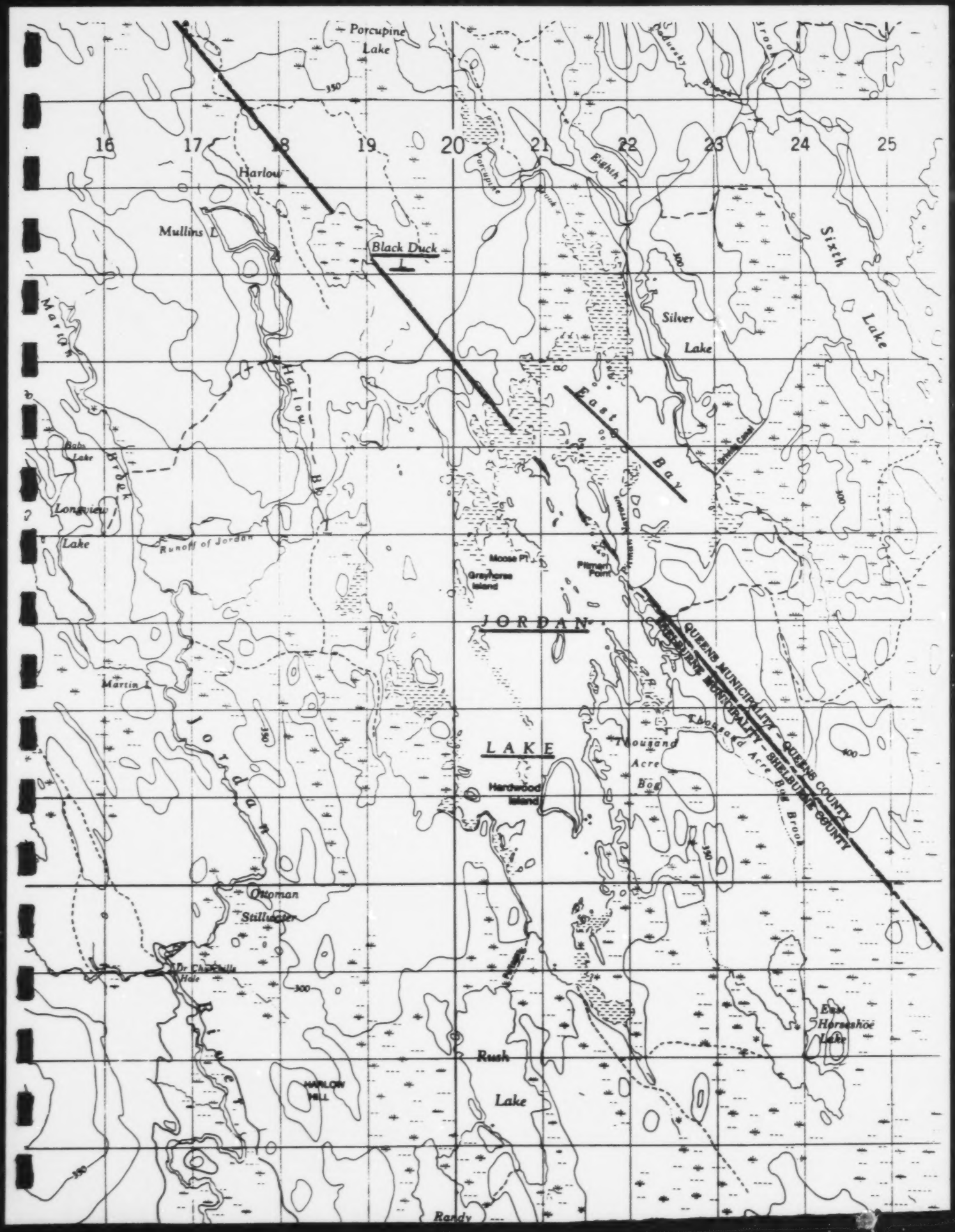

Porcupine Lake
16
17
18
19
20
21
22
23
24
25
Harlow
Mullins L.
Black Duck
Sixth Lake
Silver Lake
East Bay
Marion
Harlow Brook
Baby Lake
Longview Lake
Runoff of Jordan
Moose Pt.
Greyhorse Island
Pioneer Point
JORDAN
QUEENS MUNICIPALITY - QUEENS COUNTY
SHELBURNE MUNICIPALITY - SHELBURNE COUNTY
Martin L.
LAKE
Thousand Acre Bog
Hardwood Island
Ottoman
Stillwater
Dr. Campbells Hole
Rush Lake
HARLOW HILL
East Horseshoe Lake
Randy

Figure 3. Diagram of experimental and control area.

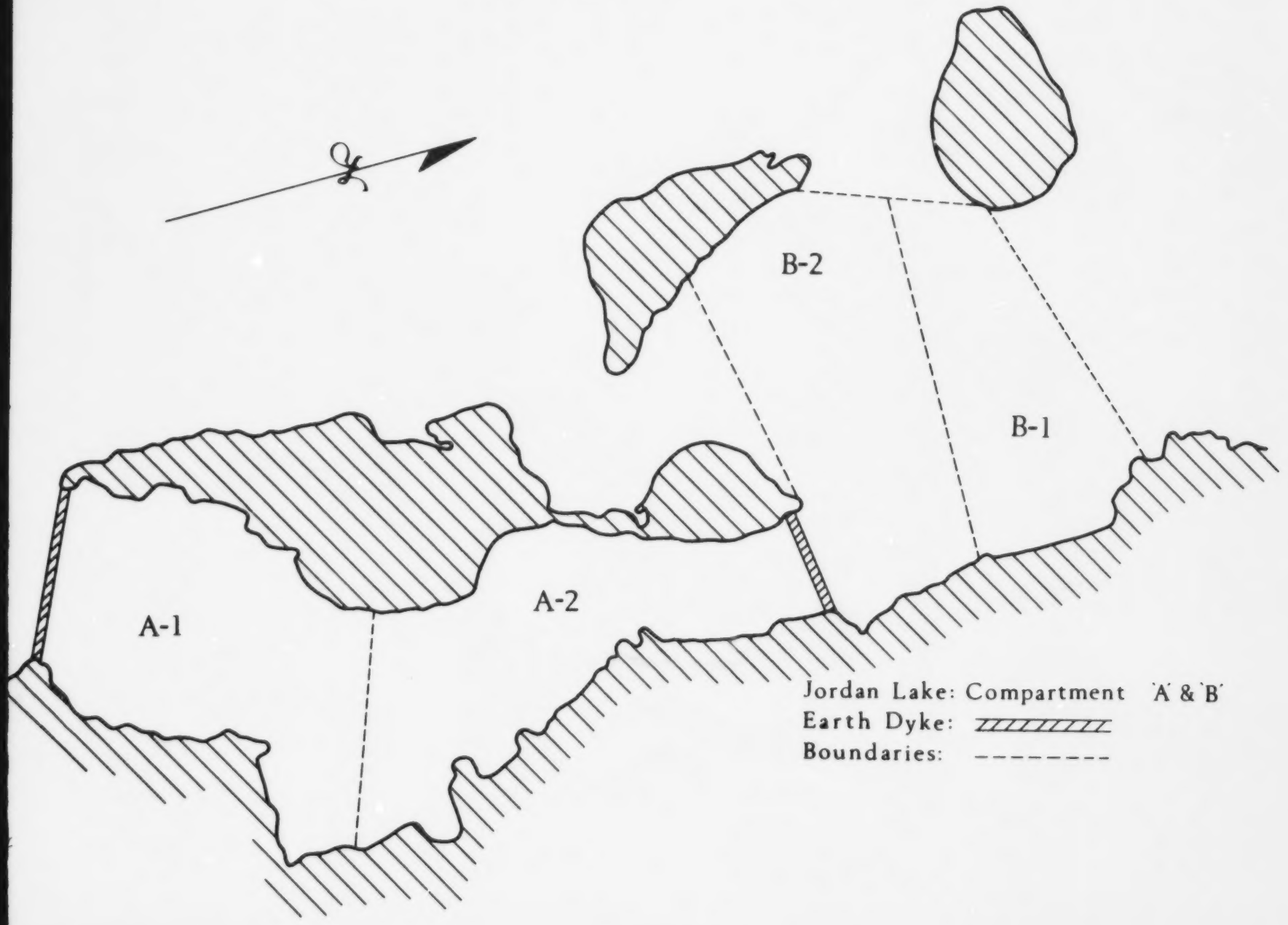

B-2
B-1
A-1
A-2
Jordan Lake: Compartment 'A' & 'B'
Earth Dyke:
Boundaries:

Figure 4. Diagram of the experimental and control area showing tower locations and invertebrate sampling points.

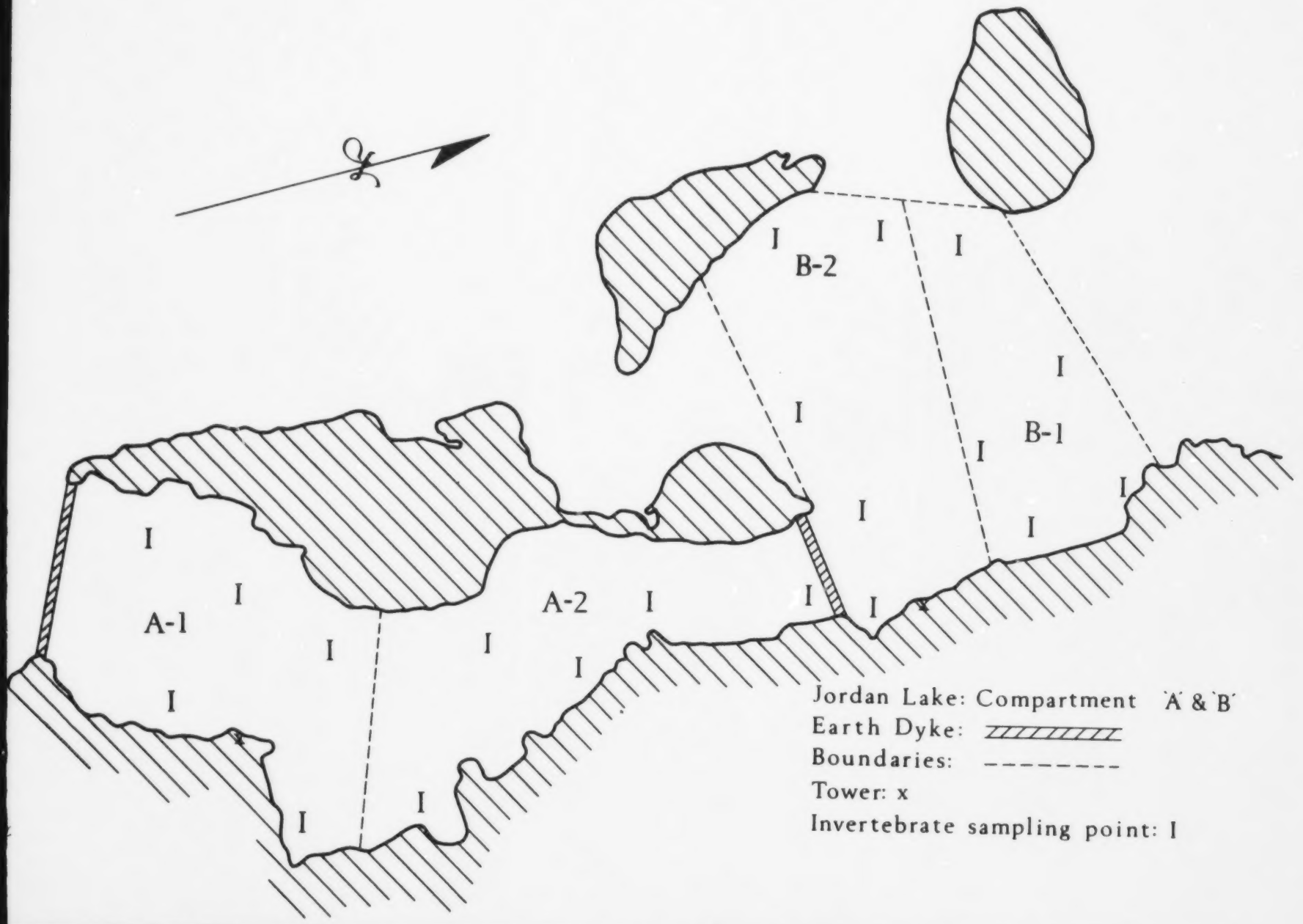

B-2
B-1
A-1
A-2
Jordan Lake: Compartment 'A' & 'B'
Earth Dyke:
Boundaries:
Tower: x
Invertebrate sampling point: I

Figure 5. Diagram of the experimental and control areas showing water and sediment sampling points.

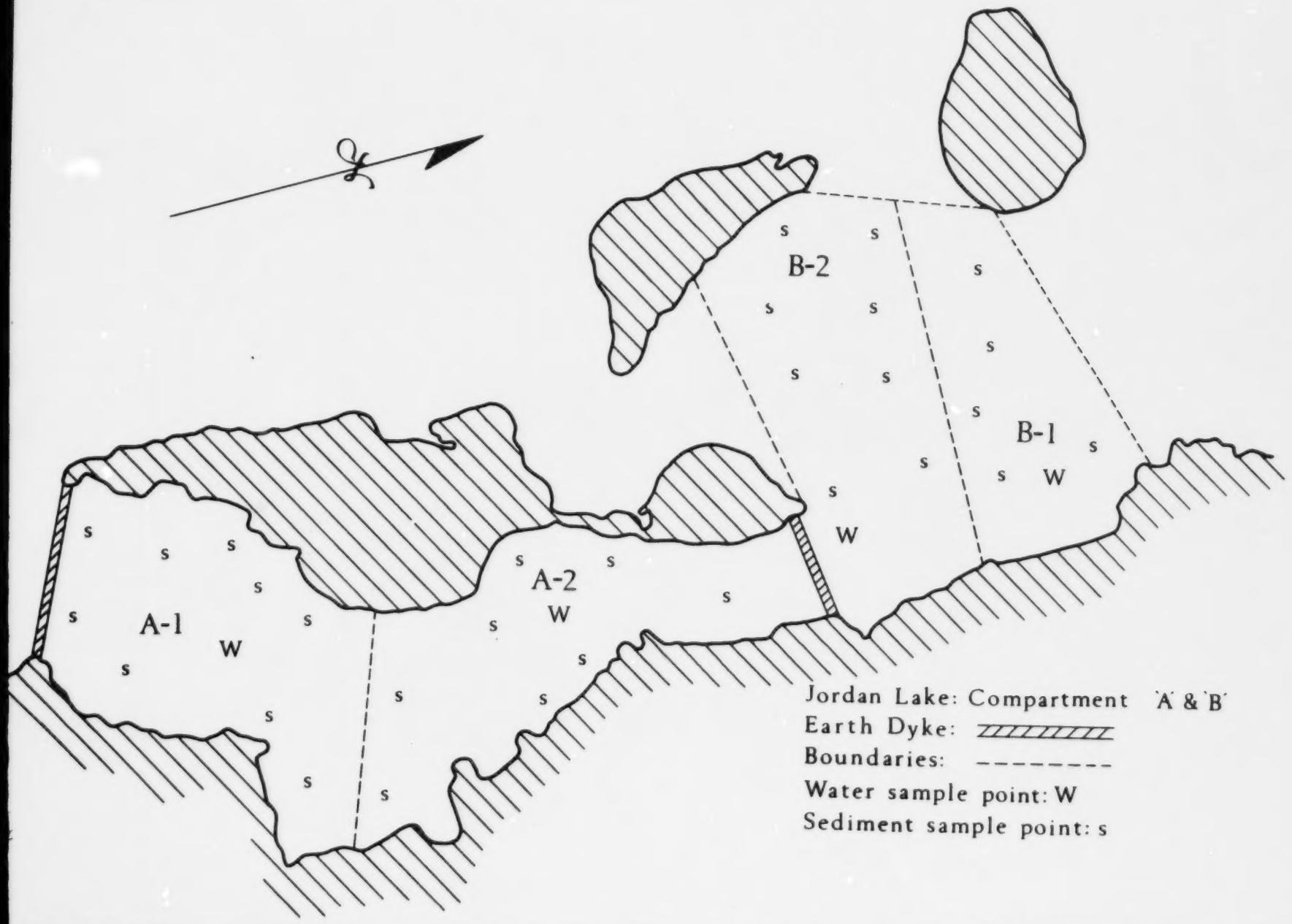

B-2
B-1
A-1
A-2
W
s
Jordan Lake: Compartment 'A' & 'B'
Earth Dyke:
Boundaries:
Water sample point: W
Sediment sample point: s

Figure 6. Diagram of the experimental and control areas showing nest box locations.

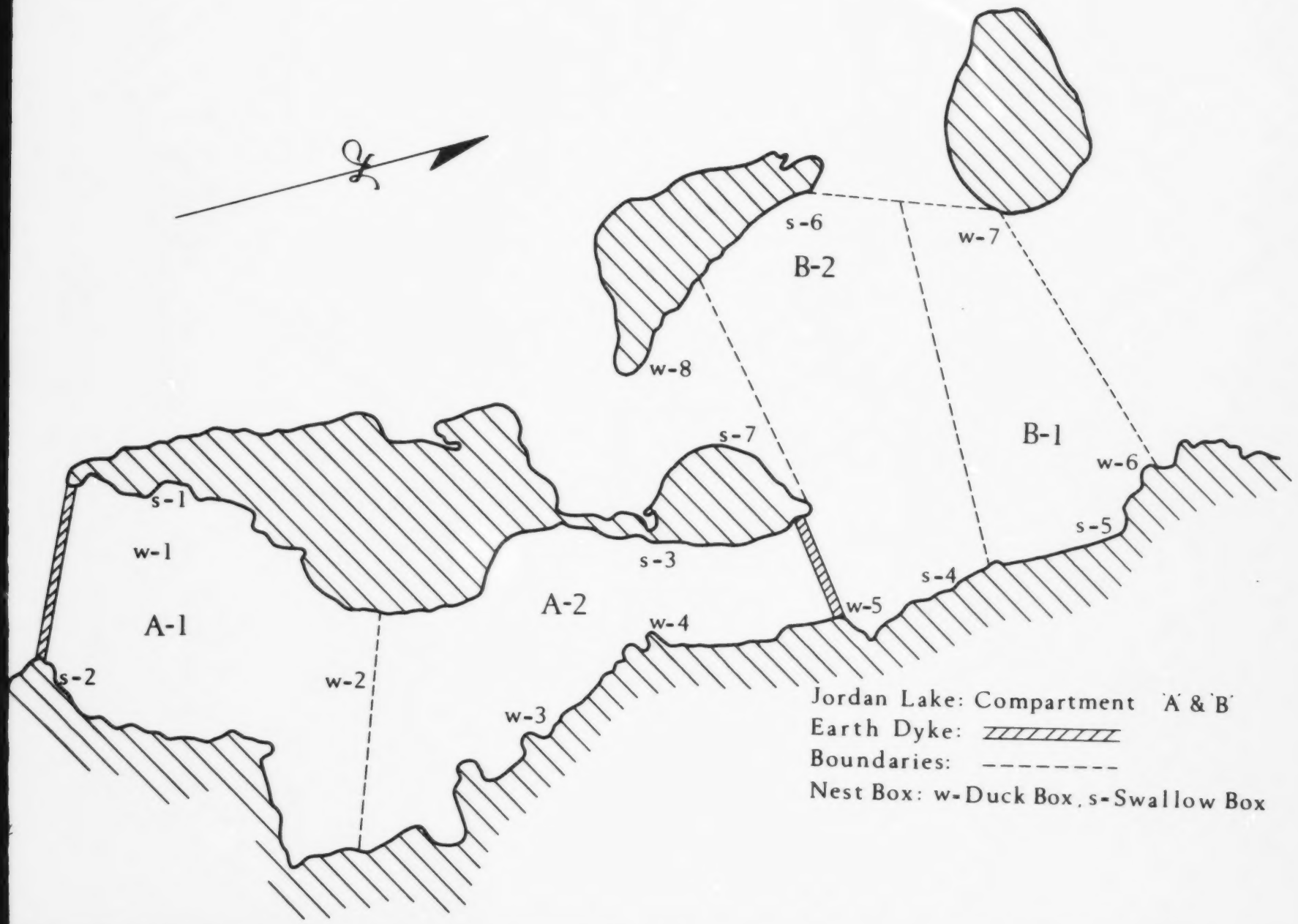

s-6
w-7
B-2
w-8
s-7
B-1
w-6
s-1
s-5
w-1
s-3
s-4
A-2
w-5
A-1
w-4
s-2
w-2
w-3
Jordan Lake: Compartment 'A' & 'B'
Earth Dyke:
Boundaries:
Nest Box: w-Duck Box, s-Swallow Box

Figure 7. Diagram of the experimental and control areas showing the vegetative transect.

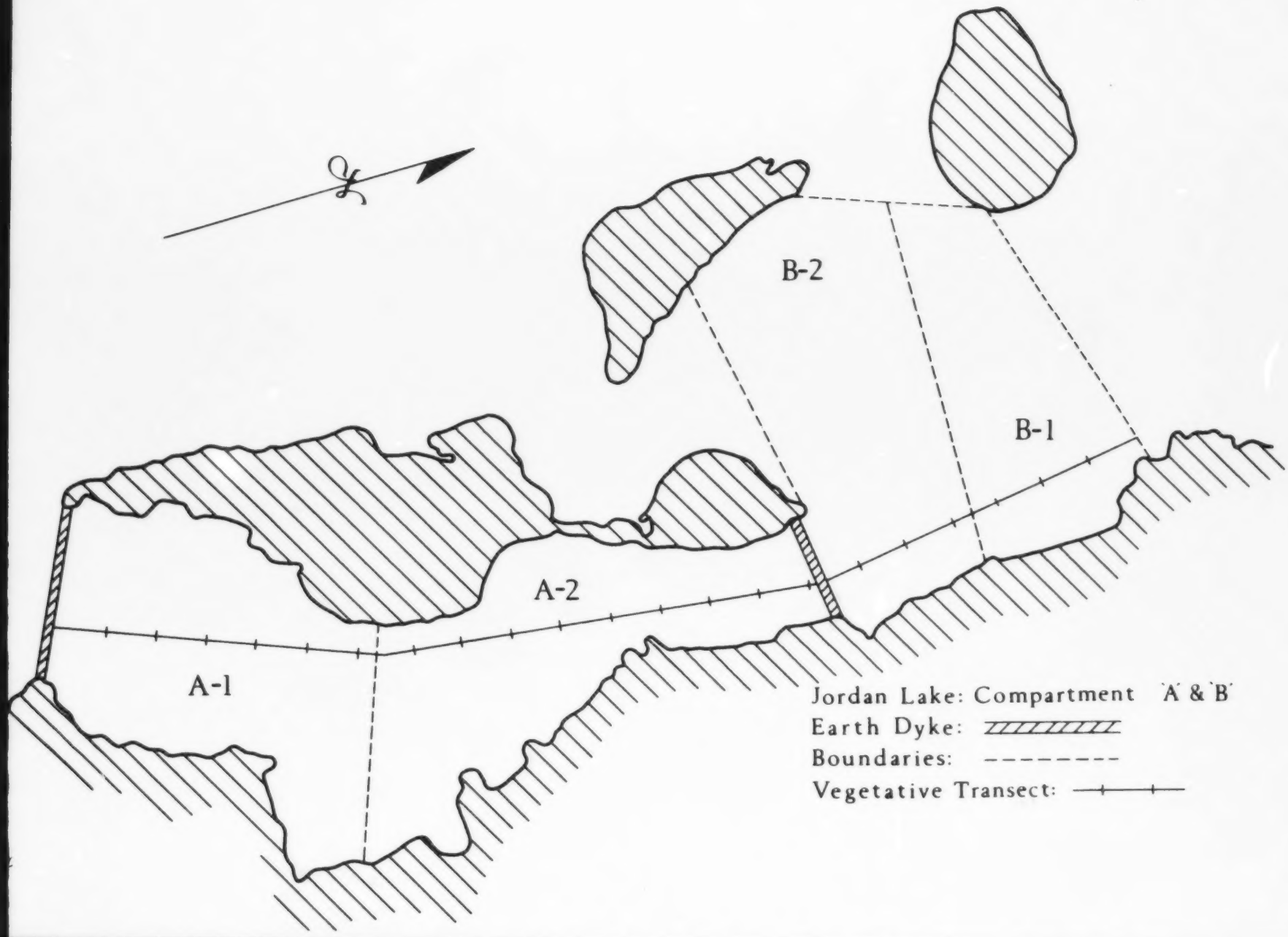
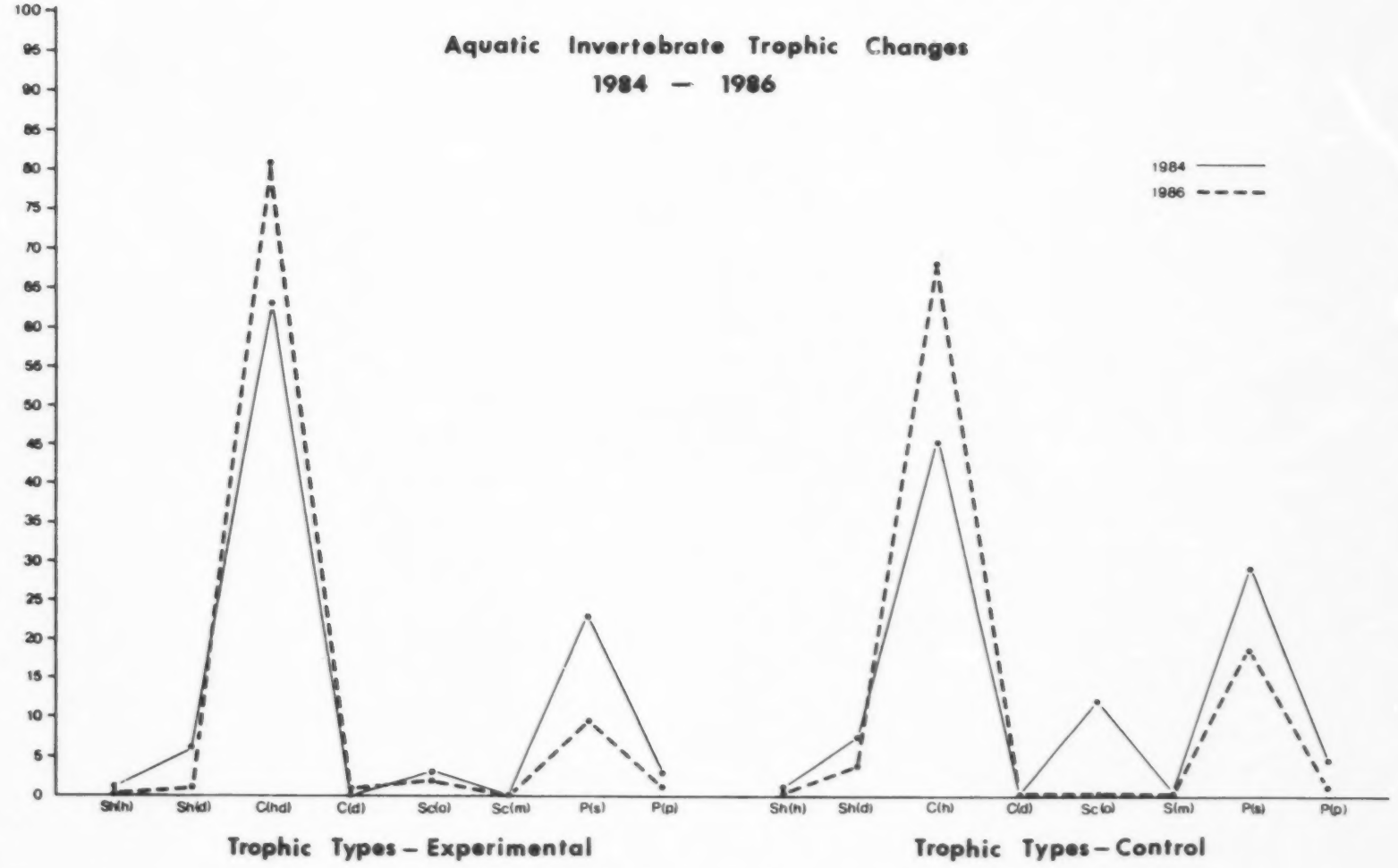

B-2
B-1
A-2
A-1
Jordan Lake: Compartment 'A' & 'B'
Earth Dyke:
Boundaries:
Vegetative Transect:

Figure 8. Graph of the aquatic invertebrate trophic changes for the experimental and control areas for 1984 and 1986.



Sh=Shredder, C=Collector, Sc=Scraper, P=Predator, (h)=herbivore, (d)=detritivore, (o)=organic, (m)=mineral, (p)=pierce, (s)=swallower

APPENDICES

Appendix A.

BLACK DUCK BROODS RECORDED - TOBEATIC WILDLIFE MANAGEMENT AREA

	1962	1967	1968	1969	1970	Helicopter June 25/84	Helicopter July 11/84	Helicopter 1977
East Jordan Bay	1	ND	0	1	3	3	4	6
Jordan Lake Total	ND	ND	ND	ND	ND	6	ND	7*
Shelburne River and Sand Lake	4	5	3	7	ND	1	3	1
Lower Porcupine	3	1	ND	1	ND	0	0	0
Black Duck Lake	1	0	ND	1	ND	0	1	0
Tobeatic Flowage	1	ND	2	ND	ND	4	5	2
Run of Jordan	ND	1	ND	ND	ND	1	ND	0
Totals							13	9

*Not included in total.

Appendix C.

A general classification system for aquatic insect trophic categories. (Cummins 1969).

General category based on feeding mechanism	General particle size range of food (microns)	Subdivision based on feeding mechanisms	Subdivision based on dominant food
Shredders	>10%	Chewers and miners	Herbivores, living vascular plant tissue
		Chewers and miners	Detritivores (large particle detritivores): decomposing vascular plant tissue
Collectors	<10%	Filter or suspension feeders	Herbivore-detritivores: living algae cells, decomposing organic matter
		Sediment or deposit (surface) feeders	Detritivores (fine particle detritivores): decomposing organic matter
Scrapers	<10%	Mineral scrapers	Herbivores: algae and associated material (periphyton)
		Organic scrapers	Herbivores: algae and associated material (periphyton)

Appendix C (Cont.)

		Swallowers	Carnivores: whole animals (or parts)
Predators	>10%		
		Piercers	Carnivores: cell and tissue fluids

Appendix D. Wildlife Observation Record Card.

Wet. No. ..... RECORD CARD Unit No. .....

Met. Grid N..... E..... Date.....

Time Period ..... A.M. P.M. To..... A.M. P.M.

Temp. ..... C. / Wind ..... kph. / ppt. ..... Cloud O

HABITAT TYPE: a. lake; b. stream; c. open water; d. marsh; e. meadow; f. flooded woods; g. forested area; h. beaver pond; i. other.

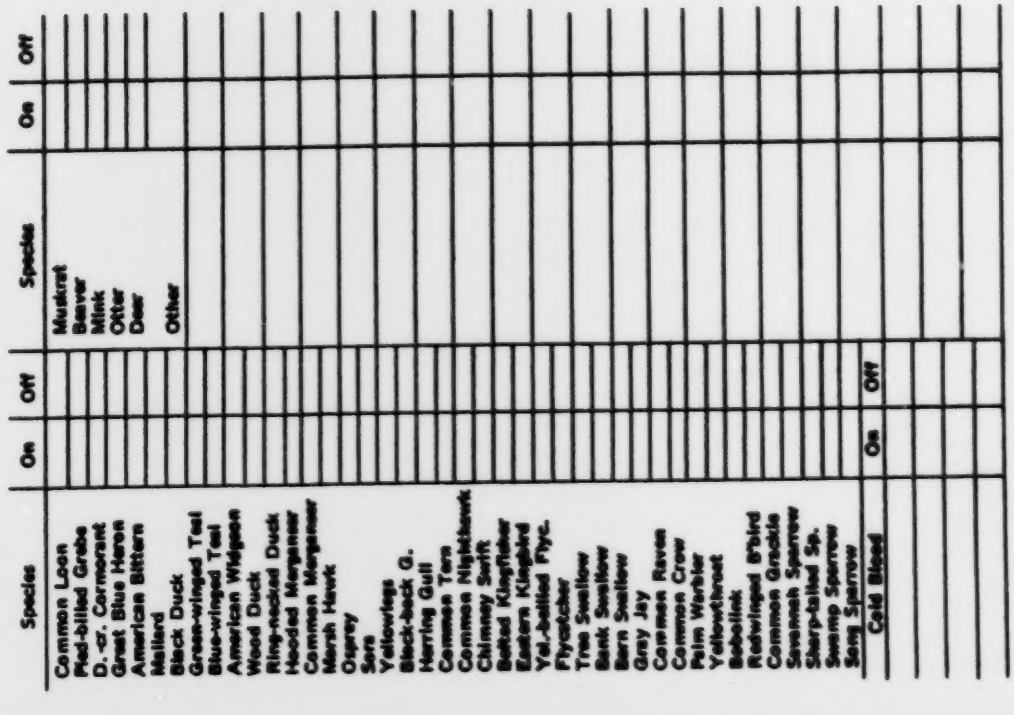
BROOD ACTIVITY: 1. disturbed; 2. feeding; 3. resting; 4. preening; 5. frolicing; 6. swimming.

Species	Female	Brood Size	Brood Class	Type Habit	Brood Activity	True Count
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

Comments: .....

Wet. Name ..... Observer.....

.....



Appendix E.

LIST OF GENERAL FEEDING CHARACTERISTICS

AND AQUATIC INVERTEBRATES THAT FALL UNDER THEM

Shredder - Herbivore:	Trichoptera Leptoceridae Triaenodes Coleoptera Chrysomelidae Coleoptera Curculionidae Coleoptera Haliplidae Peltodytes
Shredder - Detritivore:	Diptera Tipulidae Trichoptera Limnephilidae Frenesia Amphipoda Isopoda
Collector - Herb./Detr.:	Diptera Chironomidae Pelecypoda
Collector - Detritivore:	Ephemeroptera Caenidae
Scraper -Organic:	Gastropoda
Scraper - Mineral:	Trichoptera Glossosomatidae Coleoptera Elmidae
Predator - Swallower:	Diptera Heleidae Diptera Tabanidae Diptera Chironomidae Tanypodinae Trichoptera Phryganeidae Banksiola Trichoptera Polycentropodidae Cernotina Coleoptera Dytiscidae Coleoptera Gyrinidae Odonata
Predator - Piercer:	Hemiptera Hirudinea Hydracarina

Appendix E.(Cont'd.)

AQUATIC INVERTEBRATE BREAKDOWN

TO TROPHIC LEVEL

Amphipoda	Shredder - Detritivore
Hydracarina	Predator - Piercer
Coleoptera	
Gyrinidae	Predator - Swallower
Elmidae	Scraper - Mineral
Dytiscidae	Predators - Swallowers
Chrysomelidae	Shredder - Herbivore
Curculionidae	Shredder - Herbivore
Haliplidae Peltodytes	Shredder - Herbivore
Diptera	
Heleidae Bessia or Probeia	Predator - Swallower
Tabanidae	Predator - Swallower
Tipulidae	Shredder - Detritivore
Chironomidae	Predator - Swallower, Collector - Herb./Detr.
Ephemeroptera	
Caenidae	Collector - Detritivore
Gastropoda	
Ancylidae	Scraper - Organic
Physidae	Scraper - Organic
Planorbidae	Scraper - Organic
Hemiptera	
Corixidae	Predator - Piercer
Notonectidae Notonecta	Predator - Piercer
Naucoridae	Predator - Piercer
Nepidae	Predator - Piercer
Belostomatidae	Predator - Piercer
Hirudinea	Predator - Piercer
Isopoda	Shredder - Detritivore
Odonata	Predator - Swallower
Pelecypoda	Collector - Herb./Detr.

Appendix E (Cont'd.)

Trichoptera	
Limnephilidae *Frenesia*	Shredder - Detritivore
Phryganeidae *Banksiola*	Predator - Swallower
Polycentropodidae *Cernotina*	Predator - Swallower
Glossosomatidae	Scraper - Mineral
Leptoceridae *Triaenodes*	Shredder - Herbivore

Appendix E (Cont'd.)

SUMMARY OF AQUATIC INVERTEBRATE OF JORDAN LAKE
FOR 1984 AND 1986 BY TAXA AND TROPHIC CATEGORY

TAXA	GENERAL FEEDING CHARACTERISTICS	YEAR 1984 NUMBER		% TOTAL	1986 NUMBER		% TOTAL	% CHANGE NUMBERS	TROPHIC RELATIONSHIP
Amphipoda	Shredder(detritivore)	95		2.40	194		1.14	+104.2	- 1.26
Hydracarina	Predator(piercer)	23		0.58	22		0.13	- 4.3	- 0.45
Coleoptera	Shredder(herbivore)	44	(91.7)		32	(66.7)	(- 27.3)		
	Scraper(mineral)	2	(4.2)		1	(2.1)	(- 50.0)		
	Predator(swallower)	2	(4.2)		15	(31.2)	(+650.0)		
		48		1.2	48		0.28		- 0.95
Diptera	Shredder(detritivores)	1	(0.01)						
	Collector(herb/detr)	1913	(85.4)		13060	(89.8)	(+582.7)		
	Predator(swallower)	326	(14.6)		1488	(10.2)	(+356.4)		
		2240		56.54	14548		85.77	+549.5	+29.23
Ephemeroptera	Collector(detritivore)	1		0.03	213		1.26		
Gastropoda	Scraper(organic)	314		7.93	388		2.29	+ 23.6	- 5.64
Hemiptera	Predator(piercer)	117		2.95	110		0.65	- 5.6	- 2.30
Hirundinea	Predator(piercer)				136		0.80		
Isopoda	Shredder(detritivore)	95		2.40	254		1.50	+167.4	- 0.90
Odonata	Predator(swallower)	542		13.68	669		3.94	+ 23.4	- 9.74
Pelecypoda	Collector(herb/detr)	243		6.13	80		0.47	- 67.1	- 5.66
Trichoptera	Shredder(herbivore)				64	(21.3)			
	Shredder(detritivore)	64	(26.2)		23	(7.7)	(-65.6)		
	Scraper(mineral)				2	(0.7)			
	Predator(swallower)	180	(73.8)		211	(70.3)	(+11.2)		
		244		6.16	300		1.77	+ 22.9	- 4.39
	Total	3962		100.0	16962		99.97	+328.1	

Appendix E (Cont'd.)

COMPARISON OF AQUATIC INVERTEBRATES

BETWEEN THE CONTROL (C) AND EXPERIMENTAL (E) PLOTS

1984

Taxa	General Feeding Characteristics	Plot E Numbers	% Total		Plot C Numbers		% Total
Amphipoda	Shredder (detritivore)	29		1.48	66		3.29
Hydracarina	Predator (piercer)	12		0.61	11		0.55
Coleoptera	Shredder (herbivore)	21	(95.5)		23	(88.5)	
	Scraper (mineral)	---	---		2	(7.7)	
	Predator (swallower)	1	(4.5)		1	(3.9)	
		22		1.13	26		1.29
Diptera	Shredder (detritivore)	---			1	(0.1)	
	Collector (herb./detr.)	1,177	(87.6)		736	(82.1)	
	Predator (swallower)	167	(12.4)		159	(17.8)	
		1,344		68.82	896		44.60
Ephemeroptera	Collector (detritivore)	---		---	1		0.05
Gastropoda	Scraper (organic)	71		3.64	243		12.10
Hemiptera	Predator (piercer)	35		1.79	82		4.08
Hirundinea	Predator (piercer)	---		---	---		----
Isopoda	Shredder (detritivore)	42		2.15	53		2.64
Odonata	Predator (piercer)	193		9.88	349		17.37
Pelecypoda	Collector (herb./detr.)	68		3.48	175		8.71
Trichoptera	Shredder (herbivore)	---			---		---
	Shredder (detritivore)	39	(28.5)		25	(23.4)	
	Scraper (mineral)	---			---		
	Predator (swallower)	98	(71.5)		82	(76.6)	
		137		7.01	107		5.32
Total		1,953		99.99	2,009		100.00

Appendix E (Cont'd.)

COMPARISON OF AQUATIC INVERTEBRATES

BETWEEN THE CONTROL (C) AND EXPERIMENTAL (E) PLOTS

1986

Taxa	General Feeding Characteristics	Plot E Numbers	% Total		Plot C Numbers	% Total
Amphipoda	Shredder (detritivore)	2		0.02	192	3.82
Hydracarina	Predator (piercer)	12		0.10	10	0.20
Coleoptera	Shredder (herbivore)	24	(66.7)		8	
	Scraper (mineral)	1	(2.8)		-	
	Predator (swallower)	11	(30.6)		4	
		36		0.30	12	0.24
Diptera	Shredder (detritivore)	---			---	
	Collector (herb./detr.)	9,672	(93.1)		3,388	
	Predator (swallower)	714	(6.9)		774	
		10,386		87.02	4,162	82.79
Ephemeroptera	Collector (detritivore)	194		1.63	19	0.38
Gastropoda	Scraper (organic)	370		3.10	18	0.36
Hemiptera	Predator (piercer)	64		0.54	46	0.92
Hirundinea	Predator (piercer)	128		1.07	8	0.16
Isopoda	Shredder (detritivore)	221		1.85	33	0.66
Odonata	Predator (swallower)	366		3.07	303	6.03
Pelecypoda	Collector (herb./detr.)	42		0.35	38	0.76
Trichoptera	Shredder (herbivore)	29	(25.4)		24	
	Shredder (detritivore)	3	(2.6)		16	
	Scraper (mineral)	2	(1.8)		---	
	Predator (swallower)	80	(70.2)		146	
		114		0.96	186	3.70
TOTAL		11,935		100.01	5,027	100.02

Appendix E (Cont'd.)

COMPARISON OF AQUATIC INVERTEBRATES (Numbers)
BETWEEN THE CONTROL (C) AND THE EXPERIMENTAL (E) PLOTS
1984 - 1986

General Feeding Characteristics	Number 1984 E	1986 E	1984 C	1986 C	% Change 1984-86 E-E	1984-86 C-C	% Difference 1984 E to C	1986 E to C
Shredder (herbivore)	21	53	23	32	+152.3	+39.1	-9.5	+65.6
Shredder (detritivore)	110	226	145	241	+105.5	+66.2	+31.8	-6.2
Collector (herb./detr.)	1,245	9,714	911	3,426	+680.2	+276.1	+26.8	+183.5
Collector (detritivore)	———	194	1	19	———	———	———	———
Scraper (organic)	71	370	243	18	+421.1	-1,250.0	-242.3	+1,955.6
Scraper (mineral)	———	3	2	———	———	———	———	———
Predator (swallower)	459	1,171	591	1,227	+155.1	+107.6	-28.8	-4.6
Predator (piercer)	47	204	93	64	+334.0	-31.2	-97.9	+218.8
Total	1,953	11,935	2,009	5,027	+511.1	+150.2	-2.9	+137.4

Appendix E (Cont'd.)

COMPARISON OF AQUATIC INVERTEBRATES (Trophic Relationship)
BETWEEN THE CONTROL (C) AND EXPERIMENTAL (E) PLOTS
1984 - 1986

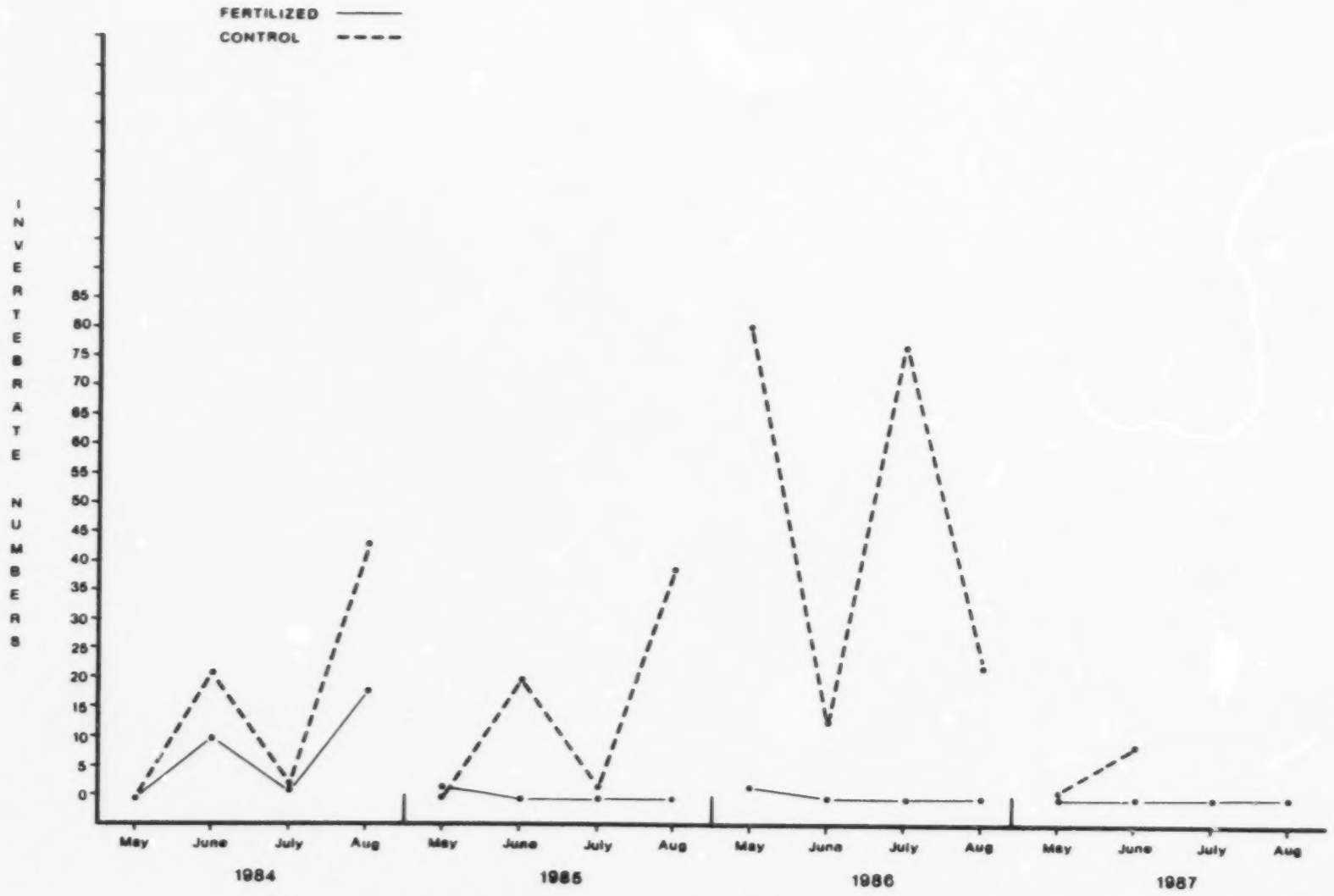
General Feeding Relationship	% of Total 1984 E	1986 E	1984 C	1986 C	% Change 1984-86 E-E	1984-86 C-C
Shredder (herbivore)	1.07	0.44	1.15	0.64	-0.63	-0.51
Shredder (detritivore)	5.63	1.89	7.22	4.79	-3.74	-2.43
Collector (herb./detr.)	63.75	81.39	45.35	68.15	+17.64	+22.80
Collector (detritivore)	———	1.63	0.05	0.38	+1.63	+0.33
Scraper (organic)	3.64	3.10	12.10	0.36	-0.54	-11.74
Scraper (mineral)	———	0.03	0.10	———	+0.03	-0.10
Predator (swallower)	23.50	9.81	29.42	24.41	-13.69	-5.01
Predator (piercer)	2.41	1.71	4.63	1.27	-0.70	-3.36
	100.00	100.00	100.02	100.00		

Appendix E (Cont'd.)

COMPARISON OF AQUATIC INVERTEBRATE (NUMBERS) BETWEEN THE CONTROL (C) AND THE EXPERIMENTAL (E) PLOTS EXCLUDING COLLECTORS HERB./DETR.)
1984 - 1986

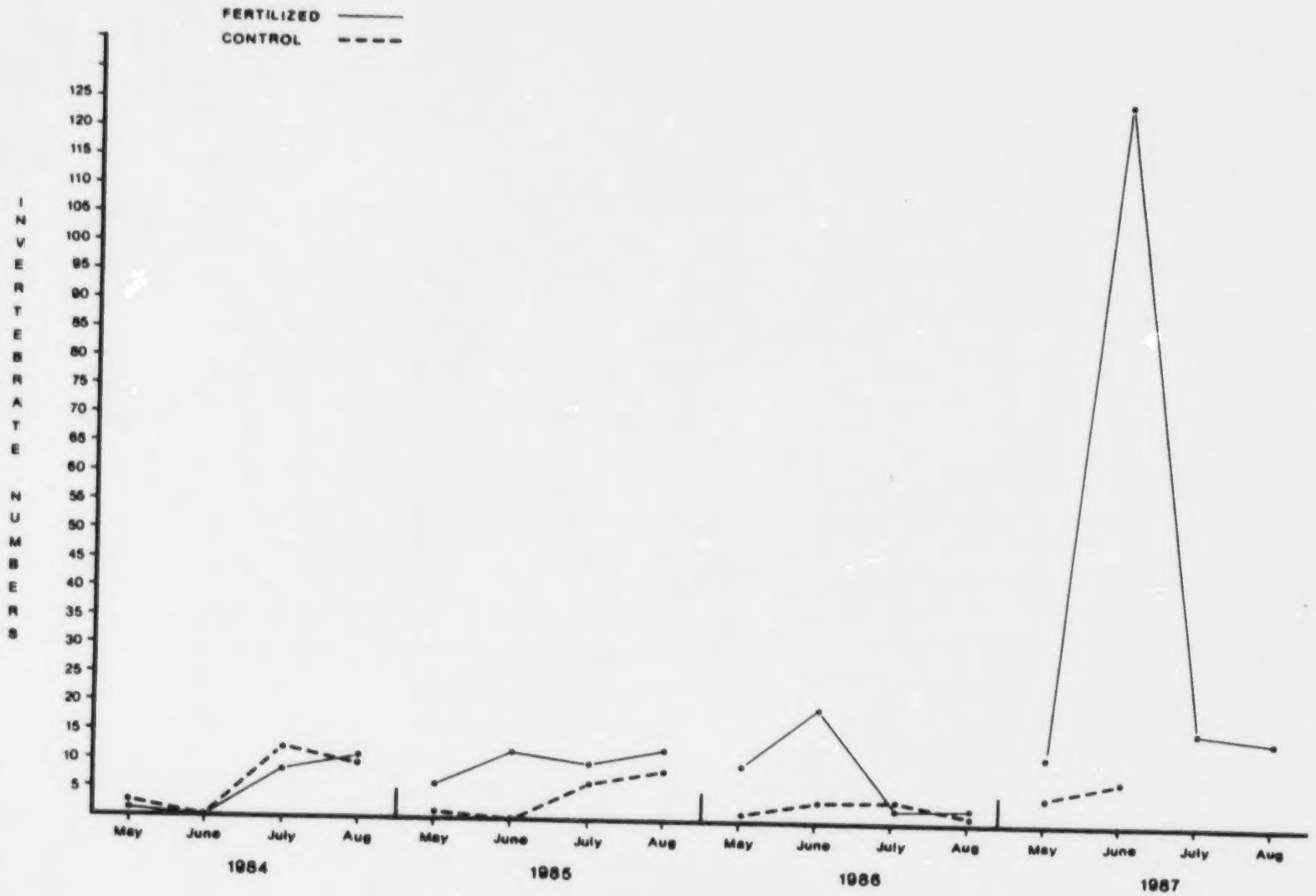
General Feeding Characteristics	Number 1984 E	1986 E	1984 C	1986 C	% Total 1984 E	1986 E	1984 C	1986 C	% Change 1984-86 E - E	1984-86 C - C
Shredder (herbivore)	21	53	23	32	2.97	2.39	2.09	-2.00	- 0.58	- 0.09
Shredder (detritivore)	110	226	145	241	15.54	10.18	13.21	15.05	- 5.36	+ 1.84
Collector (detritivore)	---	194	1	19	---	8.73	0.09	1.19	+ 8.73	+ 1.10
Scraper (organic)	71	370	243	18	10.03	16.66	22.13	1.12	+ 6.63	- 21.01
Scraper (mineral)	---	3	2	---	---	0.14	0.18	---	+ 0.14	- 0.18
Predator (swallower)	459	1,171	591	1,227	64.83	52.72	53.83	76.64	- 12.11	+ 22.81
Predator (piercer)	47	204	93	64	6.64	9.19	8.47	4.00	+ 2.55	- 4.47
Total	708	2,221	1,098	1,601	100.01	100.01	100.00	100.00	+213.70	+ 45.81

Appendix F. Aquatic Invertebrate Summaries (Numbers) by Order, Month and Year.



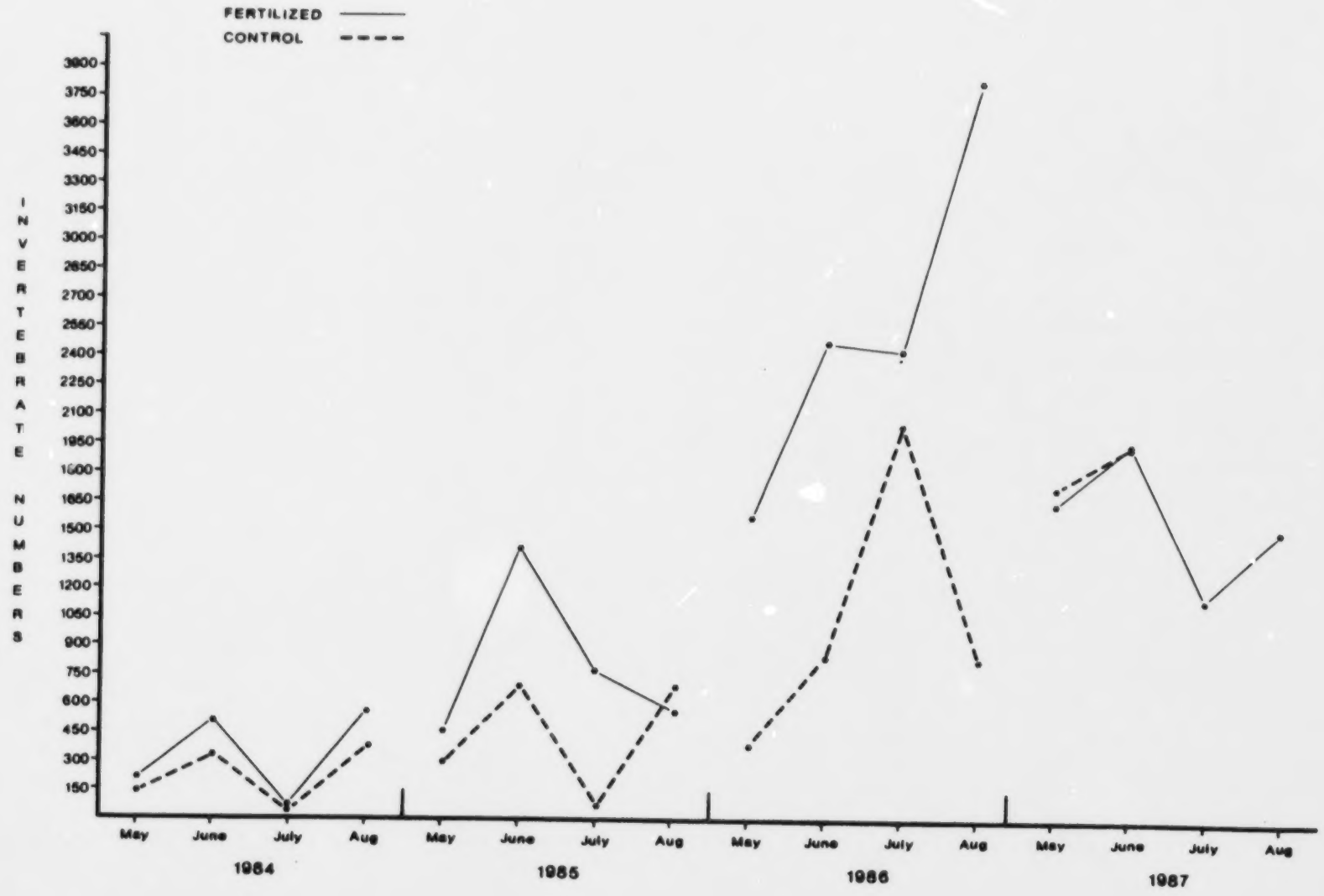
AMPHIPODA

Appendix F (Cont'd.)



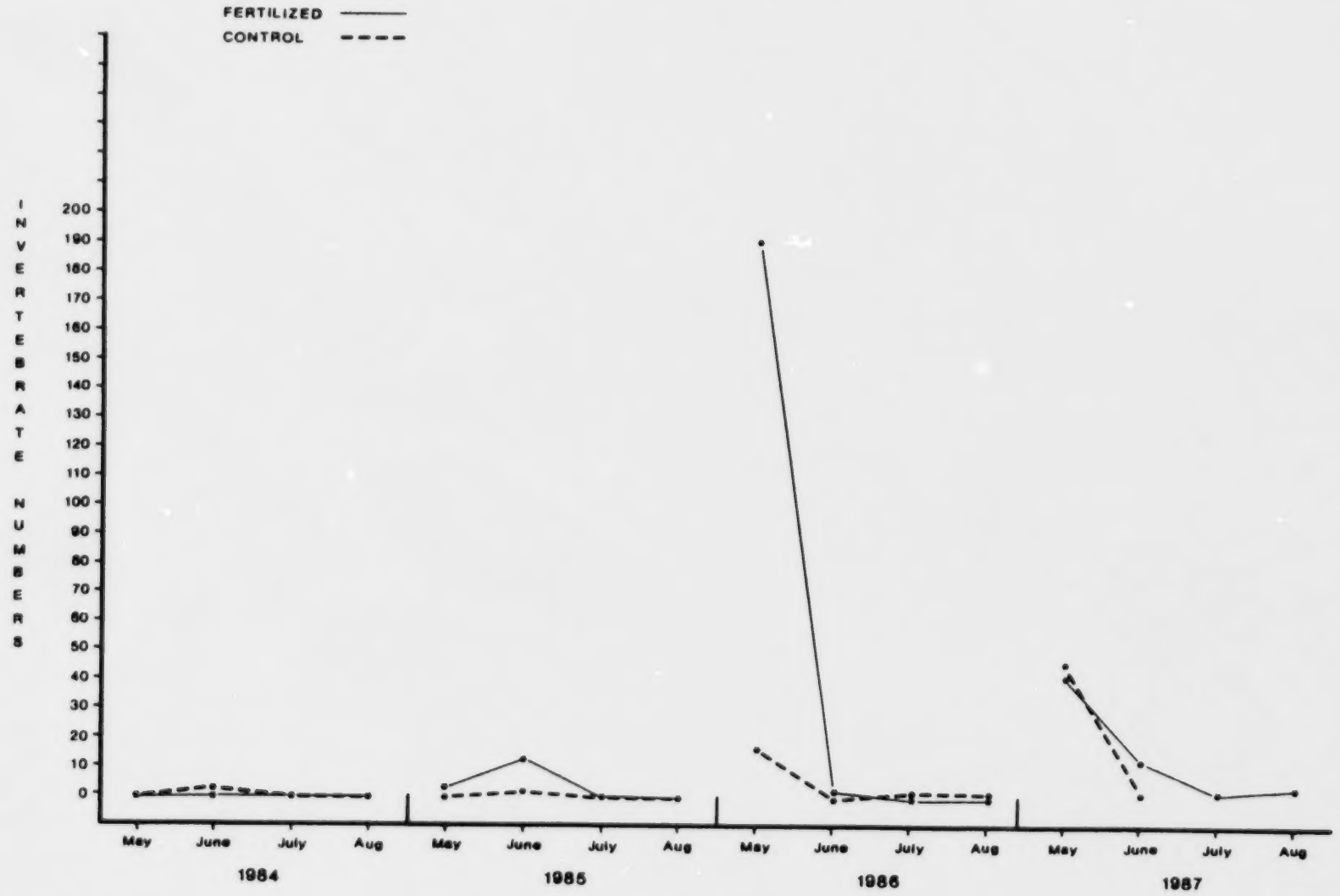
COLEOPTERA

Appendix F (Cont'd.)



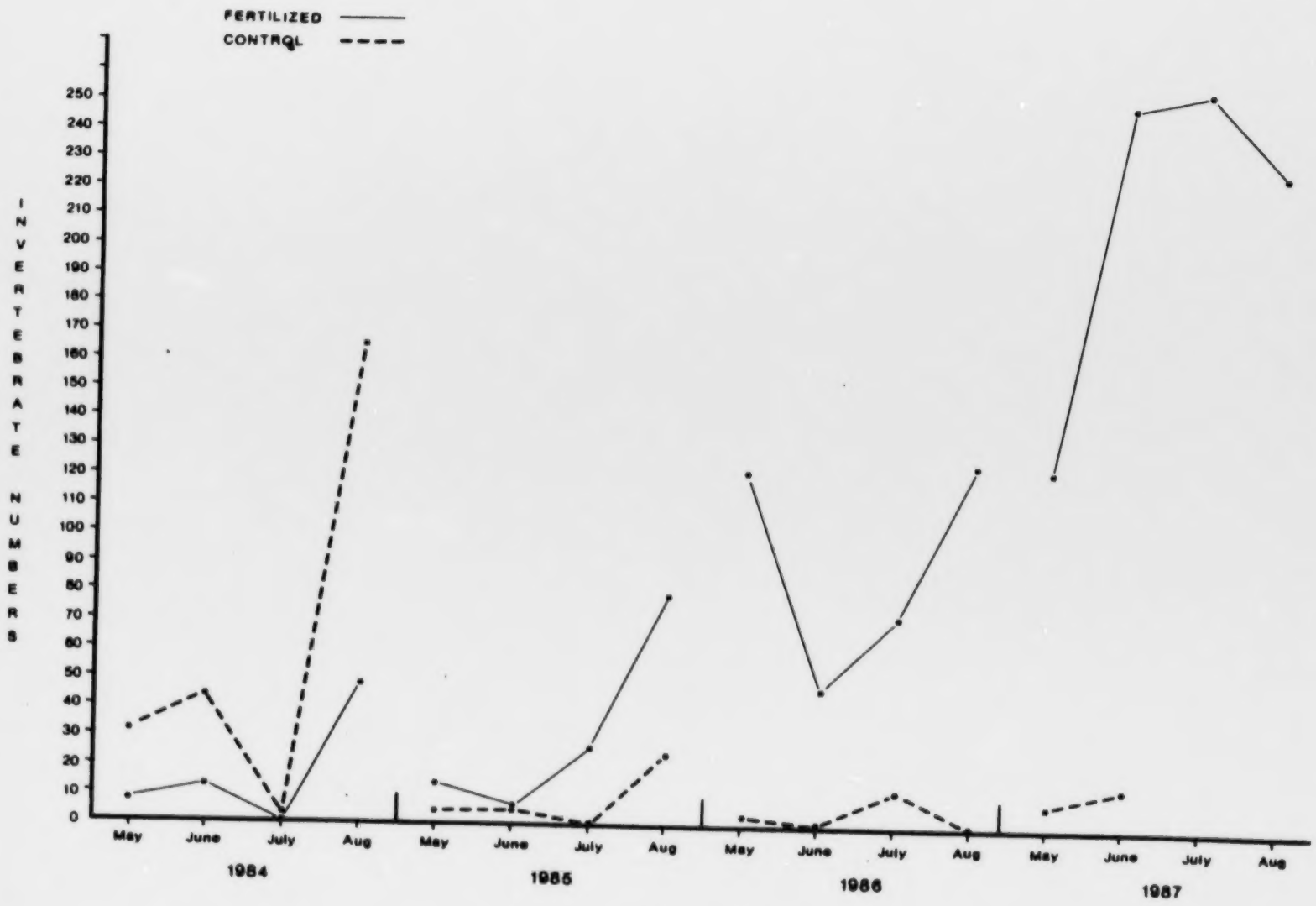
DIPTERA

Appendix F (Cont'd.)



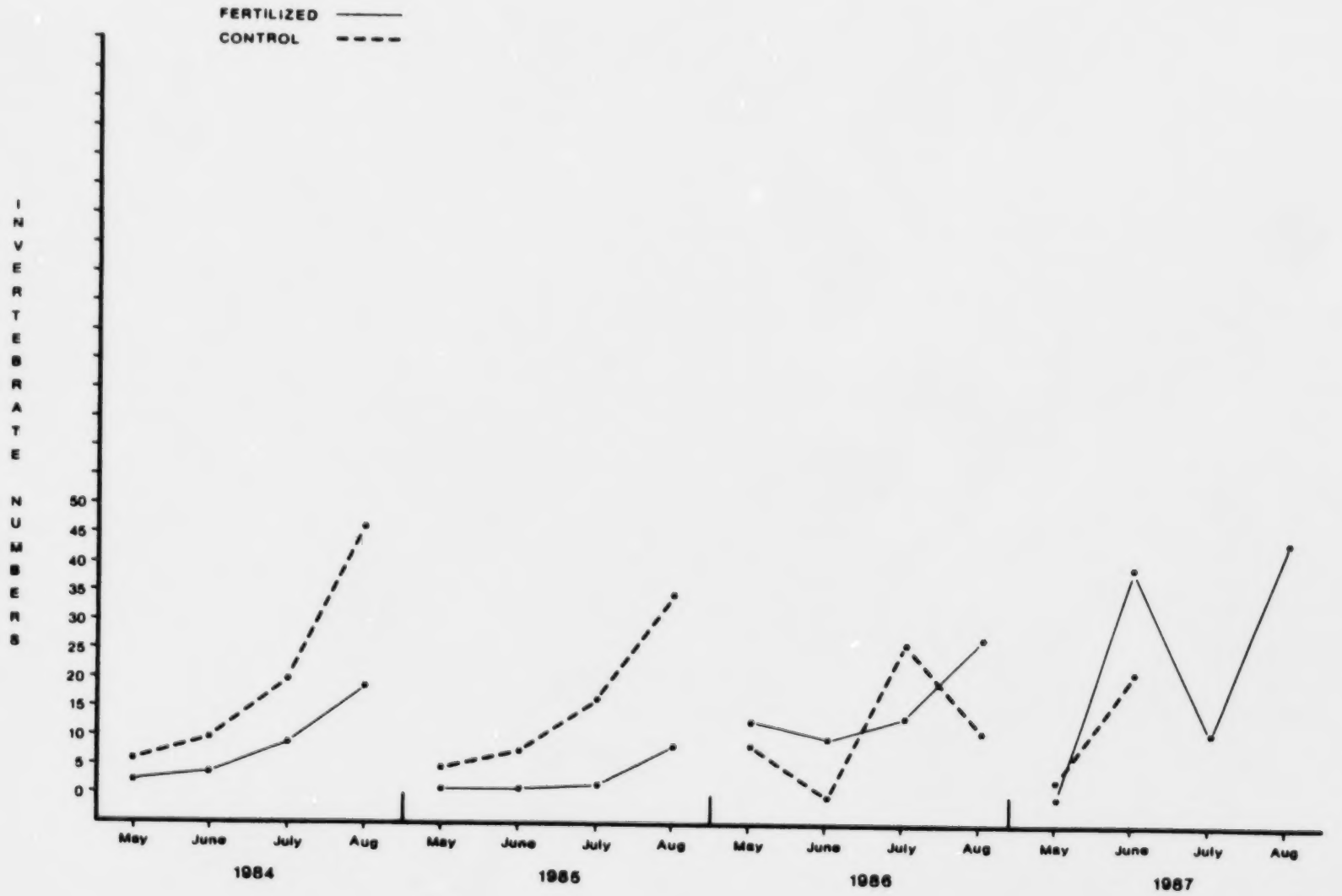
EPHEMEROPTERA

Appendix F (Cont'd.)



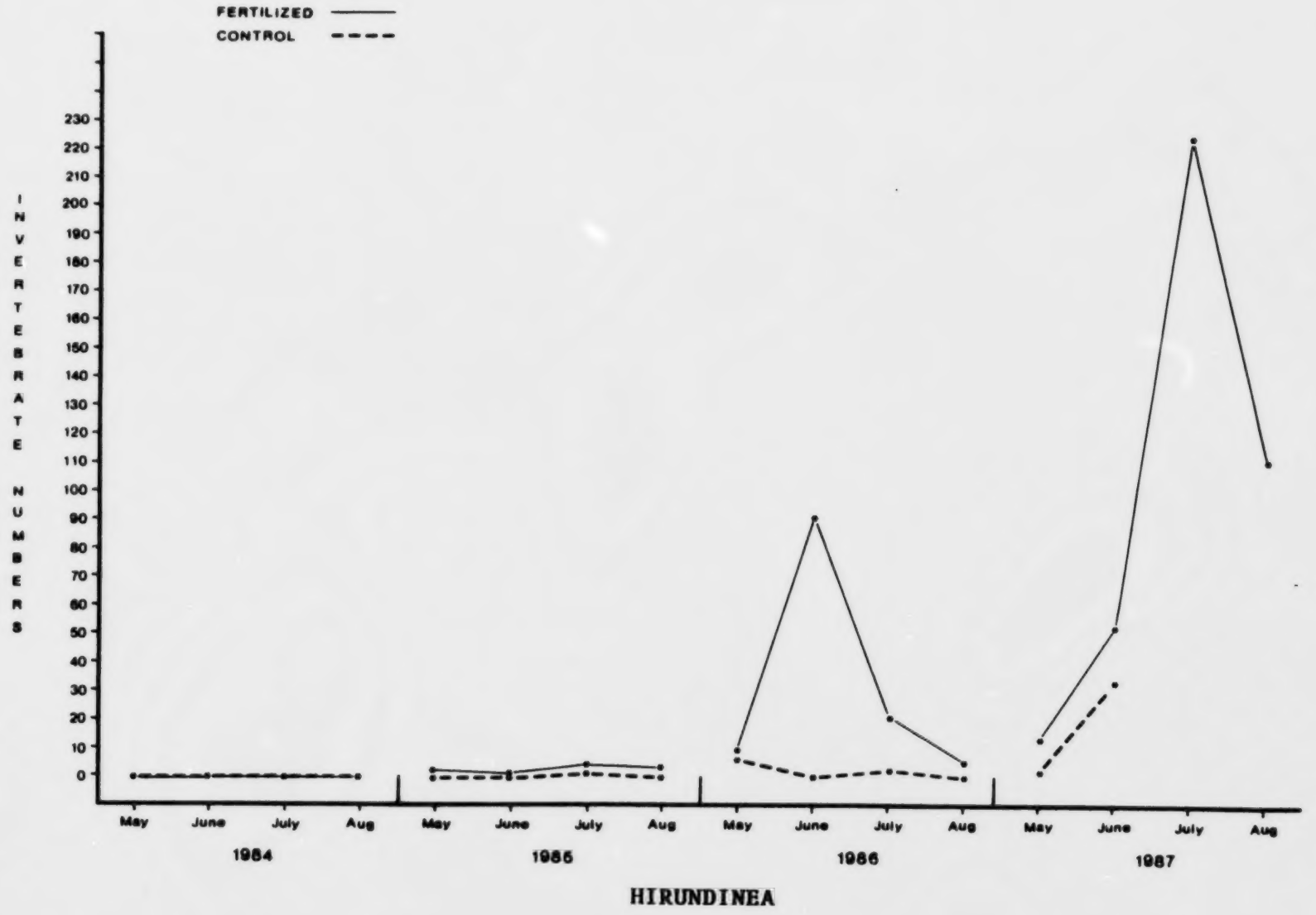
GASTROPODA

Appendix F (Cont'd.)



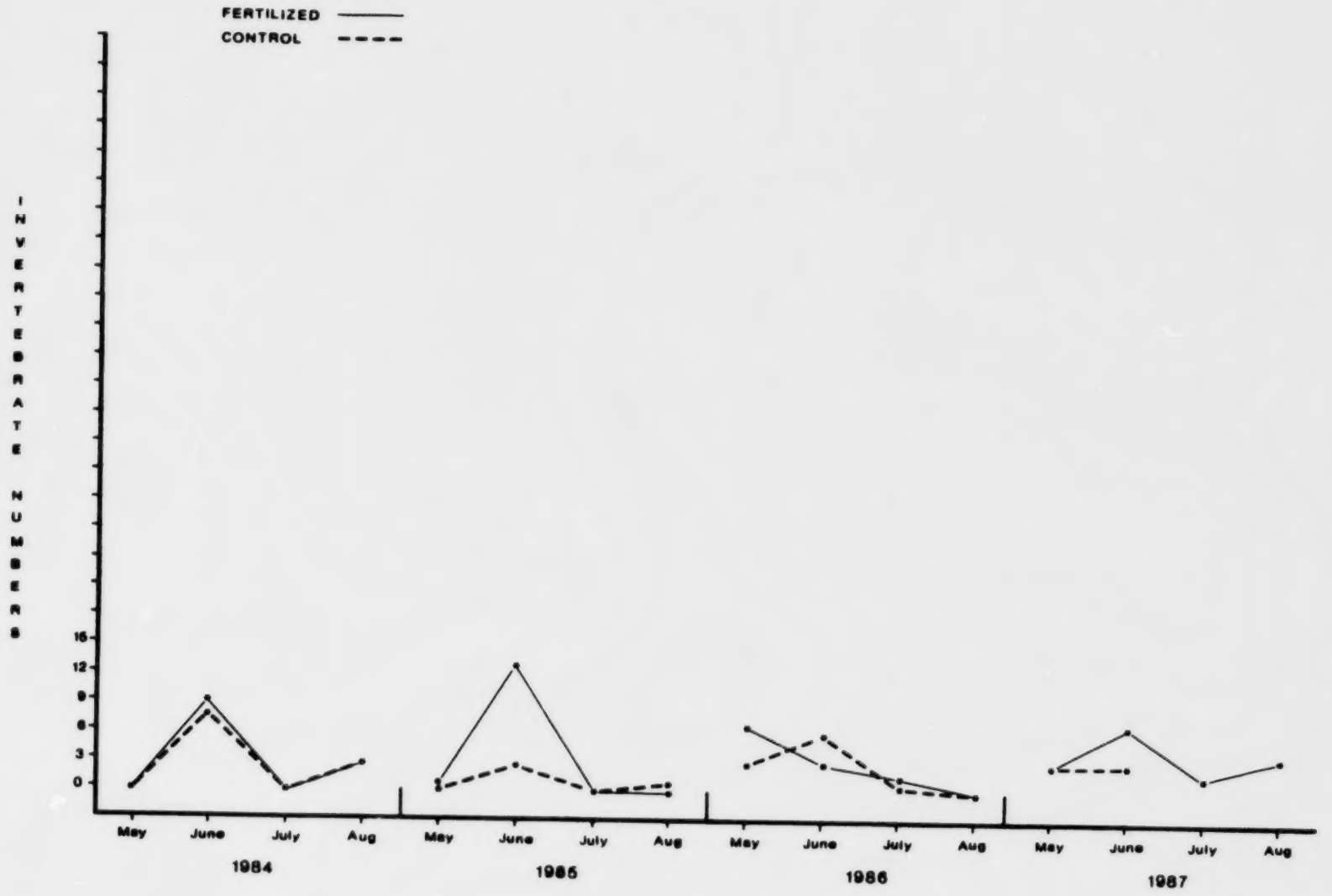
HEMIPTERA

Appendix F (Cont'd.)



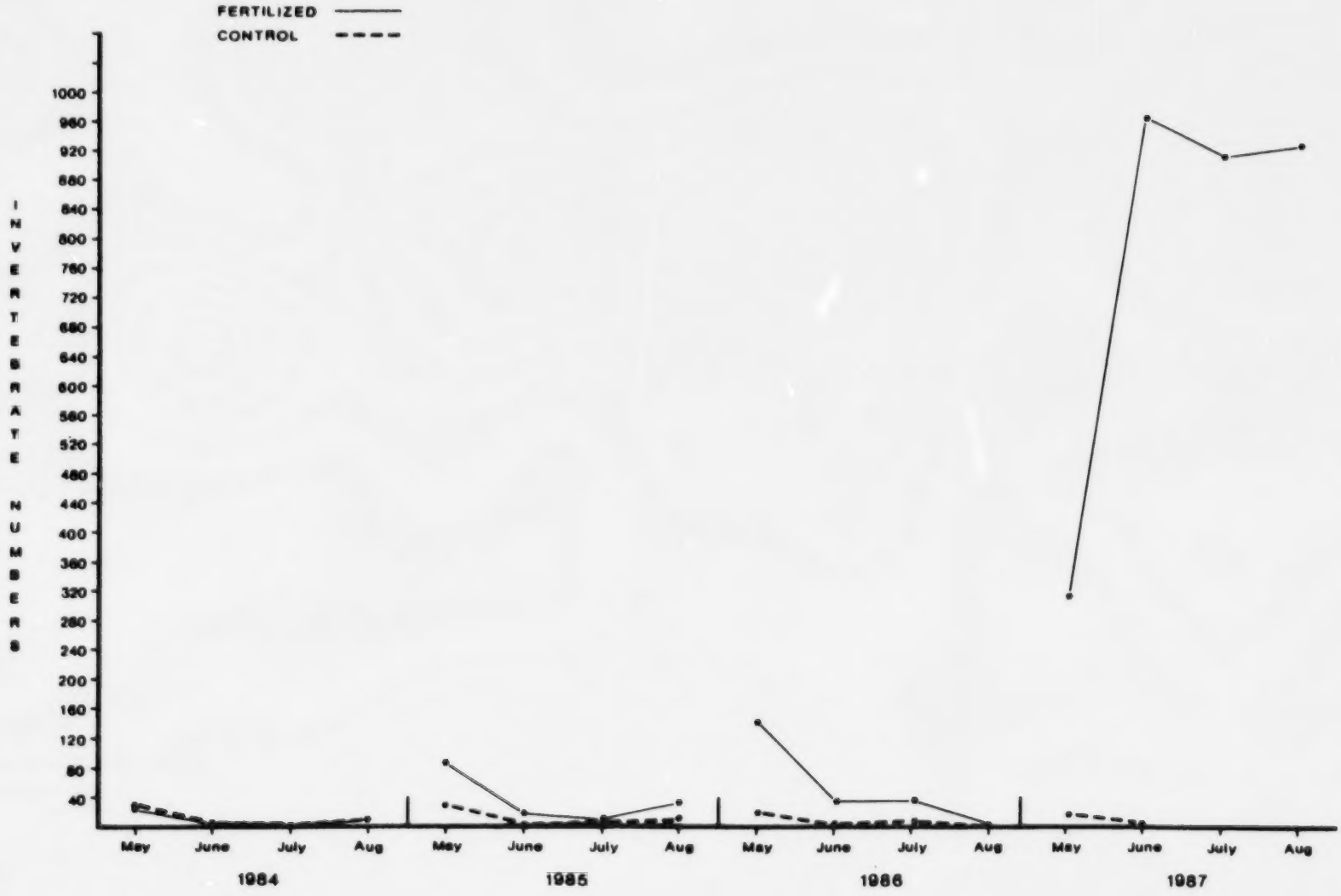
HIRUNDINEA

Appendix F (Cont'd.)



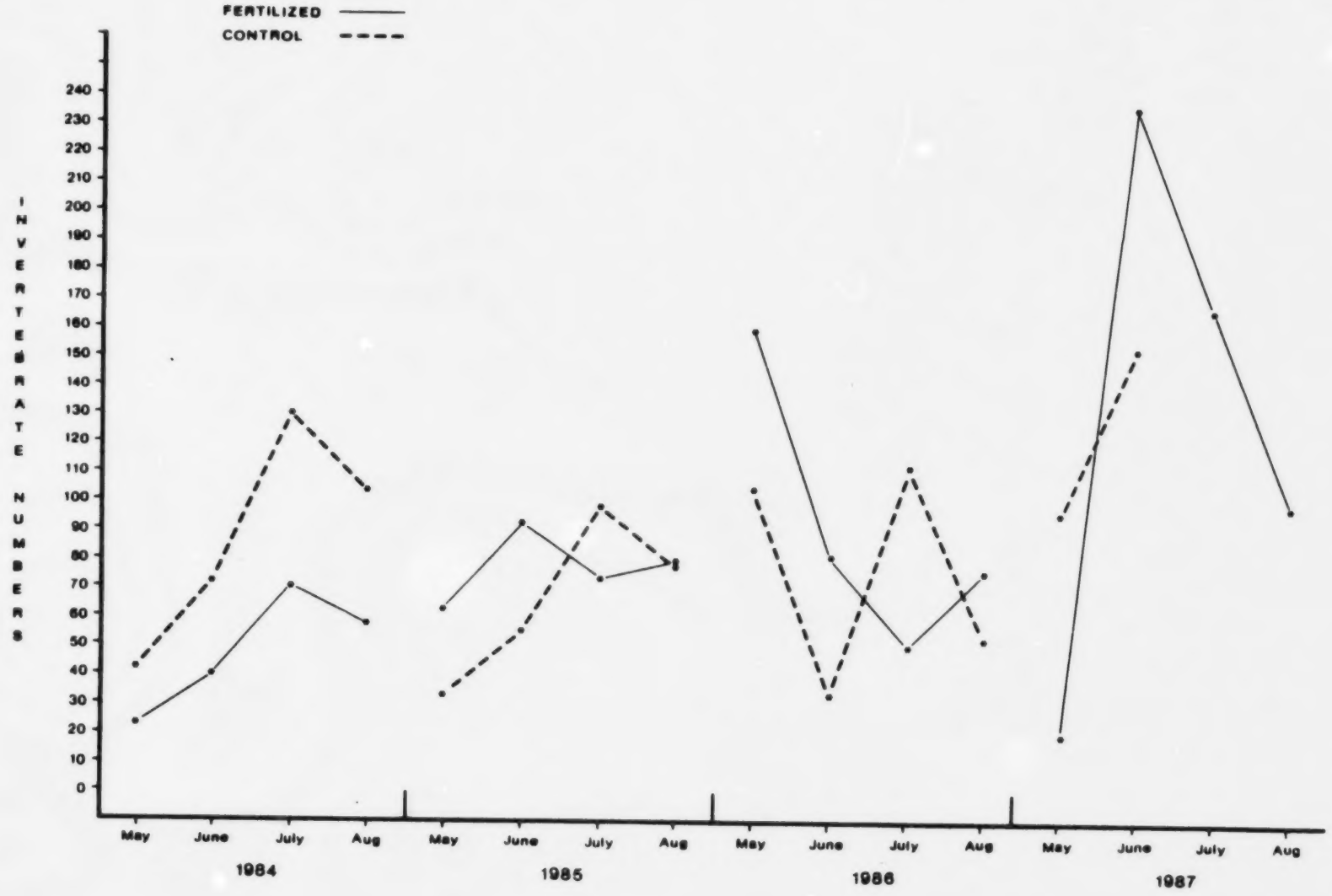
HYDRACARINA

Appendix F (Cont'd.)



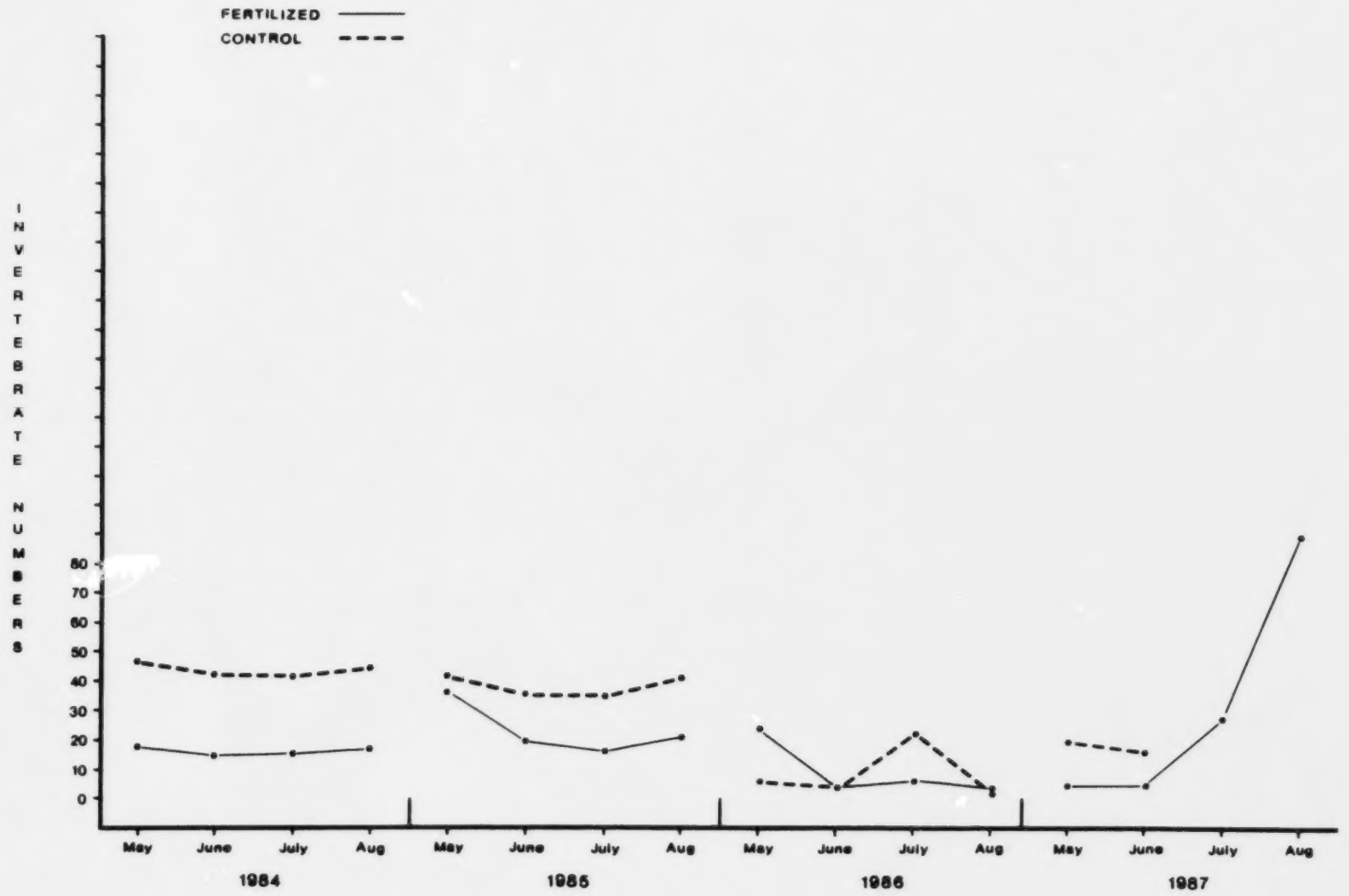
ISOPODA

Appendix F (Cont'd.)



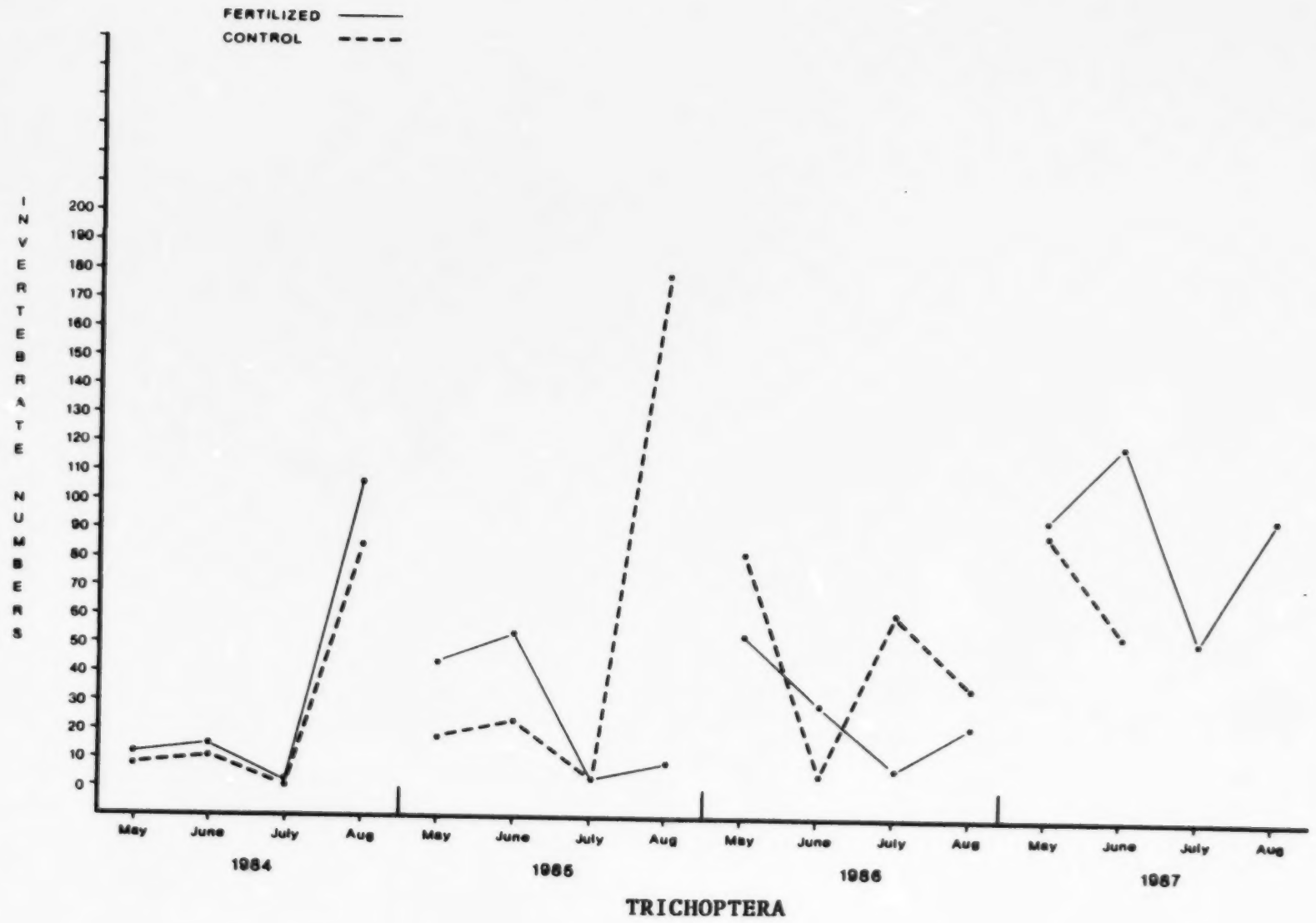
ODONATA

Appendix F (Cont'd.)



PELECYPODA

Appendix F (Cont'd.)



TRICHOPTERA

Appendix F (Cont'd.)